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DIVISION OF MATHEMATICS

POWERS OF A REAL NUMBER HAVING INTEGRAL DIFFERENCE*

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Introduction

The chief part of this paper is based on an article published jointly by Fred Supnick, J. F. Keston, and myself.[1] Several new results will be stated.

Let us begin by considering the property of uniform distribution, enjoyed by certain sequences of real numbers. A sequence of numbers p_1, p_2, p_3, . . . on the interval $[0, 1]$ is said to be uniformly distributed if each subinterval of $[0, 1]$ receives its proportionate share of the terms of the sequence: that is, if we pick any subinterval of $[0, 1]$, having length L, and denote by N' the number of terms among $p_1, p_2, \ldots, p_N$ which fall in this subinterval of length L, then $N'/N \to L$ as $N \to \infty$.

A remarkable example[2] of such a sequence was given at about the same time by Bohl, Sierpinski, and Weyl. Let us denote by (x) the fractional part of the number x; that is, $(x) = x - [x]$, where $[x]$ is the largest integer $\leq x$. Now pick any irrational number θ, and consider the sequence

$$(\theta), (2\theta), (3\theta), \ldots \tag{1}$$

It was shown that Sequence 1 is uniformly distributed on $[0, 1]$.

Some years later Koksma[3] considered the sequence

$$(\alpha), (\alpha^2), (\alpha^3), \ldots, \text{ where } \alpha > 1. \tag{2}$$

Sequence 2 clearly cannot be uniformly distributed for each $\alpha > 1$. For example, if α is an integer, Sequence 2 becomes simply 0, 0, 0, ... However, it was proved by Koksma[3] that Sequence 2 is uniformly distributed for almost all $\alpha > 1$; that is, the exceptions form a set of Lebesgue measure zero.

In addition to the fact that Sequence 2 does not yield as sharp a result as does Sequence 1, there is another interesting difference between them. We notice that the terms of Sequence 1, in addition to being uniformly distributed, are all distinct. For, if $(j\theta) = (k\theta)$, we should have $k\theta - j\theta = r$, where r is some integer. However, then $\theta = \frac{r}{k - j}$, violating the irrationality of θ.

On the other hand, Sequence 2 may allow repetitions for certain α. Besides the case when α is integral, noted above, we observe that if $\alpha = \sqrt{2}$, for example, then every even-numbered term of Sequence 2 is zero.

We have thus arrived at the central problem to be discussed here: For

* This paper was presented at a meeting of the Division on February 1, 1961.

which numbers $\alpha > 1$ will the sequence 2 admit repetitions? Equivalently stated, which numbers $\alpha > 1$ allow a solution of the equation

$$\alpha^k - \alpha^j = r \tag{3}$$

in positive integers k, j, and r?

Sharpening of the Problem

The form of Equation 3 tells us that we need consider only the case when α is an algebraic integer.[4] That is, α has a minimal polynomial of form

$$M_\alpha(x) = x^n + a_1x^{n-1} + a_2x^{n-2} + \ldots + a_{n-1}x + a_n, \tag{4}$$

where each a_i is an integer.

We next observe that a necessary condition for α to satisfy an equation of Form 3 is than $a_n < 0$. For, assuming that 3 holds, we have

$$x^k - x^j - r = M_\alpha(x) \cdot P(x), \tag{5}$$

where $P(x)$ is a polynomial with integral coefficients. Now if a_n were positive, $M_\alpha(x)$ would have at least one other positive root besides α. However, this is impossible, since the left member of 5 cannot have more than one positive root.

We have thus narrowed our consideration to the case when α is an algebraic integer whose minimal polynomial has a negative constant term.

Arrangement of Solutions of Equation (3)

Suppose we are given a fixed α, and wish to study the solutions of 3. As we run through the positive integers 1, 2, 3, ..., let us place into the same set any pair j, k such that $\alpha^k - \alpha^j$ is integral.

For example, suppose $\alpha = \sqrt{2}$. Then $\alpha^k - \alpha^j$ will be integral if, and only if, j and k are both even. Thus all the even integers will be placed together in one set, while each odd integer stands alone.

In general, then, for each fixed α we have a decomposition of the set I of positive integers into disjoint sets C_1, C_2, C_3, ..., such that j, k belong to the same C_i if and only if $\alpha^k - \alpha^j$ is integral. The sets C_1, C_2, C_3, ... will be called exponent classes, and the decomposition of I into these classes will be denoted by I/α. An exponent class containing just one element will be called unitary; if each C_i is unitary, then I/α will be called a unitary decomposition.

Thus a unitary decomposition indicates that Equation 3 has no solutions for k, j, and r.

Statement of Main Results

First, we state the expected generalization of the case $\alpha = \sqrt{2}$, considered above.

Theorem 1.[1] Suppose $M_\alpha(x) = x^n - K$, where $K > C$. Then the integers $(n, 2n, 3n, \ldots)$ comprise a single exponent class, while every other positive integer constitutes a unitary class.

As we leave the case when α is an integer or the root of an integer, it will be found convenient to denote by $L(\alpha)$ the number of nonzero terms in $M_\alpha(x)$. For $L(\alpha) \geq 3$, we find that the decomposition I/α is very much restricted:

Theorem 2.[2] If $L(\alpha) \geq 3$, then no exponent class can contain more than two elements.

In other words, if the real number $\alpha > 1$ is neither an integer nor the root of an integer, then there cannot exist three powers of α such that any two of them differ by an integer.

An exponent class containing two elements will be called binary. A trivial example of such a class is given by the number α, lying between 1 and 2, for which $M_\alpha(x) = x^3 - x - 1$; the integers (1, 3) clearly form a binary class.

Having thus established that each exponent class must be either unitary or binary, we are immediately led to the question: How many binary classes can there be for a given α? We have not yet succeeded in answering this question completely. However, we can state:

Theorem 3.[1] For any given α, at most a finite number of the exponent classes are binary.

We note that Theorems 1, 2, and 3 together imply that Equation 3 can have at most a finite number of solutions k, j and r, except in the case when α is an integer or the root of an integer.

In view of Theorems 2 and 3, we can expect the decomposition I/α to look very different in the case $L(\alpha) = 3$ than for $L(\alpha) = 2$, described in Theorem 1. In fact, we now state

Theorem 4.* Suppose $L(\alpha) = 3$; that is, $M_\alpha(x) = x^n + ax^{n-r} - K$, where $a \neq 0$, $K > 0$, $0 < r < n$. Then:

(1) If $a \neq -1$, the decomposition I/α is unitary.

(2) If $a = -1$, the integers $(n - r, n)$ form a binary class.

There will be no other binary classes, unless $M_\alpha(x)$ is of the special form:

$$M_\alpha(x) = x^{3t} - x^t - 1. \qquad (6)$$

In this exceptional case, each of the pairs $(t, 3t)$ and $(4t, 5t)$ forms a binary class, and there are no others.

Theorems 1 and 4 thus give the complete descriptions of the decompositions I/α for the cases $L(\alpha) = 2$ and $L(\alpha) = 3$. We cannot do as well

*See Theorem 7.[1]

for the case $L(\alpha) \geq 4$. However, several sufficient conditions for unitary decomposition can be stated;[1] for example:

Theorem 5.* Suppose $L(\alpha) \geq 4$, and let the minimal polynomial $M_\alpha(x)$ be given by

$$M_\alpha(x) = x^n + a_1 x^{n-1} + a_2 x^{n-2} + \ldots + a_{n-1} x + a_n ,$$

where each a_i is integral, and $a_n < 0$. Then, if all the nonzero coefficients among $a_1, a_2, \ldots, a_{n-1}$ have the same sign, the decomposition I/α is unitary.

In contrast to the above condition, involving the coefficients of $M_\alpha(x)$, we now state the following sufficient condition for unitary decomposition, in terms of the roots of $M_\alpha(x)$:

Theorem 6.** Let $L(\alpha) \geq 4$, and suppose that $M_\alpha(x)$ has a root z which does not satisfy the condition: $\alpha - 1 \leq |z| \leq \alpha$. Then the decomposition I/α is unitary.

By this time, the reader probably is aware of the fact that we have not yet exhibited any binary classes for the case $L(\alpha) \geq 4$. This gap will now be filled.

Nonunitary Decomposition With $L(\alpha) \geq 4$ †

Consider the following class of polynomials:

$$P(x) = x^{(2r-1)q} - 2x^{(2r-2)q} + 2x^{(2r-3)q} - \ldots + 2x^q - 2, \tag{7}$$

where r and q are positive integers, $r \geq 2$. Each such $P(x)$ will be irreducible, by Eisenstein's Criterion.[5] Moreover, from the identity

$$(x^q + 1) \cdot P(x) = x^{2rq} - x^{(2r-1)q} - 2, \tag{8}$$

we see that $P(x)$ has exactly one positive root α, lying between 1 and 2; thus, $P(x) = M_\alpha(x)$. Finally, 8 also shows that the integers $(2r-1)q$ and $2rq$ form a binary class of the decomposition I/α.

Of course the identity 8 depends on the particular choice of 2 as the common coefficient in 7. The special role of the "2" is further pointed up by

Theorem 7.‡ Suppose $M_\alpha(x) = x^3 - bx^2 + bx - b$, where $b \geq 3$. Then the decomposition I/α is unitary.

The Case When $M_\alpha(x)$ Is Not Given Explicitly

In all the above results, we have assumed that the algebraic integer α

*See Corollaries 4.1 and 5.1[1]

**See Corollary 5.3[1]

† See Section 11[1]

‡ The proof of this theorem will be given in a later paper.

was given to us by its minimal polynomial $M_\alpha(x)$. It may well be asked at this point whether anything can be said about the decomposition I/α in cases where α is defined otherwise than by its minimal polynomial. In particular, α might be defined in terms of another algebraic number β, whose minimal polynomial $M_\beta(x)$ *is* given.

(for example, $\alpha = a + b\sqrt{2}$, $\alpha = a + b(2^{1/3}) + c(2^{2/3})$.

In this direction, we offer the following result:

Theorem 8.* Let β be a positive algebraic number having a minimal polynomial $M_\beta(x)$ of the form:

$$M_\beta(x) = x^n - b_1x^{n-1} - b_2x^{n-2} - \ldots - b_{n-1}x - b_n,$$

where each b_i is rational and non-negative, and $n > 1$.
Let α be defined by:

$$\alpha = c_0 + c_1\beta^{d_1} + c_2\beta^{d_2} + \ldots c_m\beta^{d_m}$$

where each c_i is rational and positive, $c_0 \geq 1$, and each d_i is integral,

$$1 \leq d_1 < d_2 < \ldots \leq d_m < n.$$

Then, the decomposition I/α is unitary.

*Some Unanswered Questions***

There are, of course, many gaps left unfilled by the above set of results. In particular, we have no example of a decomposition having more than two binary classes. In fact, the case when $M_\alpha(x) = x^{3t} - x^t - 1$ (cf. Theorem 4) is the only example we have yielding more than one binary class.

Theorem 4 also raises the following question: is each of the polynomials $x^{3t} - x^t - 1$ irreducible, for $t = 1, 2, 3, \ldots$? In fact, if there exists a t_0 such that $x^{3t_0} - x^{t_0} - 1$ is reducible, then there will exist an α for which I/α has at least two binary classes; and yet $M_\alpha(x)$ will not be of the form $x^{3s} - x^s - 1$.**

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* The proof of this theorem, formulated in collaboration with F. Supnick, will be given in a later paper.

** See Section 12[1]

SECTION OF GEOLOGICAL SCIENCES

THE EXPANDING EARTH*

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About a century ago a book was published in Paris under the resounding title *La Création et Ses Mystères Dévoilées (Creation and Its Mysteries Unveiled).* Its author, Antonio Snider, tried to interpret the identity of the European and North American fossil floras according to the concept that some time ago the Europeans and African continents were in a close connection with the two Americas, but that a rifting took place between these continents and that they have drifted apart, bringing about in the course of hundreds of millions of years the present pattern of oceans and continents.

The idea seemed to be too daring and fantastic, and it was entirely forgotten. However, 50 years later it came to the foreground again. Taylor (1910) intended to explain by a similar assumption the forces of mountain building. The same idea was also adopted by Wegener (1915) who, from the striking similarity of the African and South American coasts, concluded that the continents were close together at one time. Wegener also accumulated much evidence from different disciplines to prove his point. The idea of continental drift was a very attractive one, but it nevertheless invited serious opposition that failed to abate even after Wegener's death.

About 1950 the situation was characterized by the circumstance that both geologists and geophysicists refuted the idea of continental drift for the good reason that they know of no appropriate source of energy that could have brought about the displacement of the continental masses; neither was the assumption of the swimming of the continental crust above its substratum any too convincing.

However, the triumphal dance over the corpse of the Wegener theory did not last long. It was at that time that the palaeomagnetic investigations were begun. By these it became possible to determine the location of the poles in the geological past. The results of these measurements were in a fair agreement with data derived from palaeoclimatology: the latitudes determined palaeomagnetically corresponded with the climatic latitudes derived from geological observations (Irwing, 1956).

On the other hand, the measurements have shown that in the geological past the continents were much closer than at present, that is, that in the course of earth history the continents have drifted apart, as proposed by the Wegener theory.

* This paper was presented at a meeting of the Section on February 6, 1961.

The apparent contradiction between the palaeomagnetic data and the general repudiation of the theory can be eliminated by assuming that the earth is expanding. In the case of over-all earth expansion, the sialic crust of the earth, which must have been a contiguous shell to begin with, was subjected to tension and, at a given value of this tension, it was torn. Due to the tensional forces acting, the parts of this shell drifted apart and the rift was filled by the higher-density mass of the deeper Earth shells. This process was repeated several times in the course of the earth's development. One of the episodes of this process was the formation of the Atlantic basin. It is apparent that this explanation does not imply a motion of the continental parts with respect to their substratum.

The above-described mechanism accounts for the petrological differences between continental and oceanic areas and also for the double maximum of the hypsometric curve, as well as for the discontinuity on the continental and oceanic areas. If the surface of the present continents is considered to represent the original surface of the primordial earth, the initial radius of the earth can be computed. Comparison of the original radius with the present-day one yields an annual radius increase of 0.7 mm.

Let us now consider whether the assumption of earth expansion can be proved in some way or other.

Geological considerations lead us to believe that the mass of sea water did not change significantly in the course of earth history; the changes, if any, tended toward an increase of the water mass by a few per cent.

Taking this statement as a basis, it is possible to check the expansion idea by considering the change of water-covered continental surface in the course of earth history. Indeed, for a shrinking earth the water-covered area must increase, for an earth of constant volume it must be constant, and for an expanding earth it must decrease.

The paleogeographical date by the Termiers and by Strahov has yielded the results presented in the figures (FIGURES 1 and 2). Both figures show a trend indicative of earth expansion. The radius increase derived from these graphs amounts to 0.4 to 0.8 mm. per year (Egyed, 1956).

Many other facts suggest the expansion of our planet; of these I may mention particularly only Heezen's (1960) results concerning the mid-oceanic drift systems.

By what mechanism and by what earth model is it possible to interpret the expansion and of what order of magnitude are the energies involved? The essentials of the new dynamic earth model are as follows.

Disregarding the uppermost 100 to 300 km. of the earth that were in a position to undergo significant differentiation, the earth consists of three modifications of a chemically more or less homogeneous silicate substance. The inner core corresponds to the first modification, the outer core to the second, and the mantle to the third. First modifications

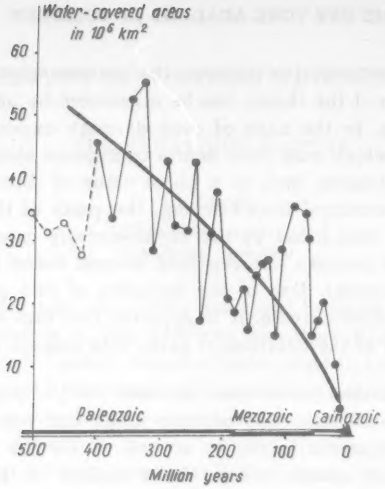

FIGURE 1. Water-covered continental areas in the different geological epochs computed from Termier's maps.

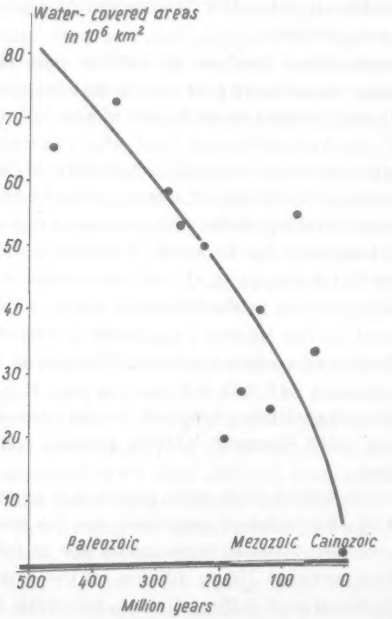

FIGURE 2. Water-covered continental areas in the different geological epochs computed from Strahow's maps.

are unstable and there is a steady decomposition of these modifications into the stable one. The transition is irreversible and results in a steady decrease of the earth's mean density. This, however, causes an increase in volume.

The energy liberated on transition amounts to about 15 to 20 ev per molecule. This is the order of magnitude of the energies of ionization, and it coincides with the energy difference between the metallic and nonmetallic states.

According to Ramsey (1959), the metallic state is reached at a certain critical pressure. In a depth h, at the boundary of the core, the critical pressure is given by

$$pk = \int_0^h 6(z)g(z)dz$$

$6(z)$ being the depth-density relation of the column of matter, and $g(z)$ the gravity acceleration. According to the mechanism expounded above, the surface of critical pressure is gradually shifted towards the interior. This is possible, however, only if the gravity coefficient, f, decreases with time instead of being a universal constant as was believed since Newton. This assumption however, is in agreement with one of Dirac's (1938) conclusions, who stated at about the end of the 1930s that the gravity coefficient varies inversely as a time parameter, that is,

$$f = \frac{x}{t}$$

where x is a constant and t is a steadily increasing time parameter.

C. Gilbert (1956) has proved that Dirac's somewhat confusing results can be derived by reasonable assumptions from the general theory of relativity. A still more striking result was that the time parameter derived from the present-day value of the gravity constant was found to be 4.1 billion years, almost equal to the earth's age as determined by radioactive methods.

The Dirac-Gilbert results permit the establishment of the correct expansion mechanism, and also the computation of the rate of expansion from physical data. There is one point of uncertainty in this computation, namely that the density jump on the boundary of the inner core is unknown. Therefore it is possible to determine only the minimum amount of expansion, which is 0.3 mm. per year (Egyed and Stegena, 1958).

The idea of an expanding earth is, however, hard to reconcile with the hitherto proposed theories of the earth's origin, so that this new assumption necessitates a reconsideration of its earliest history.

The problem of the earth's origin is the same as the problem of the origin of the solar system. A theory concerning the origin of the solar

system must explain the organization characterizing that system; it must be in agreement with facts of observation concerning the earth and its interior, and it must be built upon the basic principles of physics.

It can be shown that the condition for the origin of the planets from the sun, with the conservation of angular momentum, is the same as the physical condition for earth expansion, that is, for the validity of the Dirac-Gilbert equation. On the other hand, on the basis of Dirac-Gilbert equation it can be shown that the earth originated from the sun (Egyed, 1960).

Let us now consider the consequences of this equation for the development and structure of the earth.

The structure of the mass that escaped from the sun was initially determined solely by the pressure distribution in its interior and by the distribution of high-pressure phases dependent on it. The number of high-pressure phases was greater than at present, since the average density then amounted to about 35 gcm. $^{-3}$ instead of the present-day 5.52 (FIGURE 3). Only the uppermost shell of a 150- to 200-km. thickness was in the state corresponding to that of today's mantle. Considering the enormous

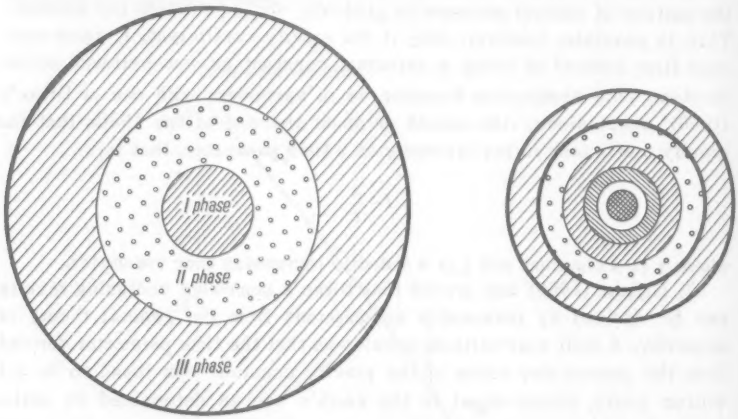

FIGURE 3. The structure of the earth at present and at the time of its origin.

amount of energy liberated on escape, this thin mantle was certainly in a molten state. Farther below, matter existed in high-pressure states of higher density. Thus the arrangement of the masses in the earth's interior, according to increasing density, did not come about as a result of some kind of differentiation, but was rather due to the pressure gradient that has permitted the existence of higher-pressure phases at greater depths. Of these phases, only the relatively thin layer of crust and mantle was in an unregenerated state.

The substance of the mantle, being of a chemical composition similar to the whole earth's average, was situated in a very strong gravity field.

The gravity field was strong for two reasons: (1) the radius of the earth was about one half the present one, and (2) due to the Dirac-Gilbert equation at small values of t, the gravity acceleration would have exceeded several thousand times its present value. This intense gravity field brought about a very thorough differentiation. As a result of differentiation, there developed in the uppermost part of the earth an acidic, silica-rich shell, underlain by more basic differentiation products. Above the silicate layer, there followed layers of water vapor of denser gas mixtures and, farthest out, of light gases, Consequently, differentiation produced out of the average magma characteristic of the primordial earth the first hydrosphere and atmosphere, the acidic crust enveloping the whole of the earth and the basic and ultrabasic shells situated beneath the crust.

At the same time, the increase of t has brought about a rapid decrease of gravity, in the sense of the relation $f = \frac{x}{t}$. Consequently, the intense differentiation of the mantle substance in the intense gravity field soon came to an end, and the rest of the mantle substance yielded by phase transitions later on, did not undergo significant differentiation. Its chemical composition must therefore be equal to that of the primordial undifferentiated earth.

Considering, however, that the hydrosphere and atmosphere were derived from this primordial stellar matter, as was the crust, which is acidic in its upper part and basic only in the deeper layers, it follows that the average composition of the earth is less basic than that of the deeper part of the crust, and even less so than the substances directly underlying the crust. It follows also that this part of the mantle must be considerably richer in gases and water vapor than the crust and the immediately underlying layers. All this implies that its density, reduced to surface pressure, must also be smaller.

Density and the velocity of propagation of elastic waves vary directly as the basicity of the silicate substance. The above statements may be expressed graphically as presented here. On the other hand, density and elastic-wave velocity also increase with pressure (FIGURE 4).

Of the three graphs, it is most simple to check the third one, which suggests that the velocity-depth relation of the elastic waves must present a local minimum. This minimum corresponds, according to the theory of wave propagation, to a channel that captures most of the energy of the waves entering it. There exists indeed such a channel. It is the low-velocity channel, attributed by Gutenberg (1953) to thermal causes. The above considerations postulate, however, that it be dependent on differences in chemical composition. Let us now seek a method by which to choose between the above-mentioned possibilities.

If the Gutenberg channel is due to thermal causes its depth should be a function of the isothermal surfaces. These, however, are – provided that the existence of convention currents is refuted – very depth-sensitive and close to the equipotential surfaces of gravity. Therefore, the depth of

the channel must be nearly constant. If, on the other hand, the channel is due to differences in material composition, due to the above-mentioned mechanism of differentiation as governed by the Dirac-Gilbert equation, then the expansion of the earth is also to be assumed, and the depth of the Gutenberg channel must have been seriously disturbed in the course of the earth's history. Clearly the depth of the channel must be less where the superficial shells of the earth have thinned out considerably.

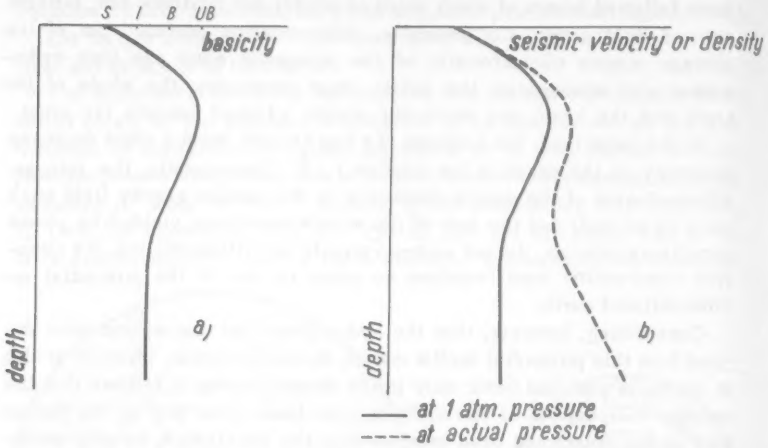

FIGURE 4. The variation of basicity with depth (left), the variation of density, or seismic velocity, with depth at 1 atm. pressure, and the variation of density or seismic velocity with depth at the actual pressure (right) of the substances constituting the earth.

Research by Dorman *et al.* (1960) concerning the dispersion of mantle waves has now proved the existence of the Gutenberg channel, on the one hand and, on the other, the fact that in oceanic areas this channel occurs at a depth of about 60 km.; beneath the continents this value is from 120 to 150 km., in agreement with our conclusions. The thermal explanation would demand just the opposite. Similar results were arrived at by Vesanen and his coworkers (1959). Therefore the Gutenberg channel emerges as a feature due to differences in chemical composition beneath the earth's crust.

We have inferred above that the part of the mantle situated beneath the Gutenberg channel, which marks the maximum of basicity, must be less basic, about dioritic or diorite-gabbroic in composition, very rich in volatiles. What are the geological and tectonic consequences of this assumption?

It is well known that along parts of the Pacific coast and along parts of the Alpine chain as well, there exist belts of very deep-focus earthquakes. These belts of earthquakes, representing deep scars in the earth's mantle, are accompanied by an andesitic volcano belt. In recent times

andesitic volcanism is accompanied throughout by earthquakes of focal depth sometimes exceeding 700 km. In areas of predominantly basaltic volcanism, the maximum depth of earthquake foci is about 70 km. Whereas basaltic volcanism is generally poor in volatiles, one of the characteristic features of andesitic volcanism is the abundance of gases and volatiles.

These features are readily interpreted by the above assumption as scars reaching down to depths exceeding 700 km. and offer a direct connection with the intermediate, volatile-rich substance of the great depths; these substances surge along the deep fractures to the surface because of the pressure drop. By their high temperature, these substances leach out, dissolve, and melt the walls of the fracture, and by these processes the dioritic or diorite-gabbroic rock of the effusions is formed. The magma are characterized by a high concentration of volatiles. The melts and volatiles surging upwards mobilize many rare elements from the adjacent rocks, and that is why the areas of andesitic volcanism are generally rich in certain kinds of ore, whereas basaltic volcanism developed in the uppermost parts of the mantle is generally poor in ores.

The above mechanism can be applied to the moon also. The moon is coeval with the earth. The earth-moon system is a double planet. According to the Dirac-Gilbert equation and to Ramsey's results, the mantle of the moon must have been relatively much thicker at any given time than that of the earth. Therefore initial differentiation must have involved a shell of much greater thickness. Consequently the "continental" crust of the moon must be thicker than that of the earth. If this is true, the difference between the two peaks of the hypsometric curve must be greater for the moon than for the earth. Indeed, according to investigations by Joksch (1957) this level difference amounts to some 7.9 km. on the moon. On the other hand, if the same value is computed for the earth, compensating for erosion and sedimentation, a value of 5.6 km. is obtained. This is in accordance with the above considerations. However the amount of gases escaping on differentiation also must be greater in the case of the moon's thicker mantle. This is perhaps the reason for the formation of the lunar craters. A magma much richer in gases than the terrestrial magmas is likely to solidify much like rising dough. After the first solidification, the tension of the gases causes several explosions of great intensity, and that is why the lunar craters are situated so nicely along Baldwin's explosion graph. In all, the craters of the lunar "terrae" are explosion scars of an intensely gaseous acidic crust. The "maria" are, on the other hand, rifts due to expansion that took place subsequent to differentiation.

From the mechanism of evolution of the mantle there also follows the mechanism of development of the primordial atmosphere and hydrosphere. That is, the hydrosphere was not formed gradually out of juvenile gases and vapors transported by magmatism and volcanism but, to at least 80 per cent, by the differentiation of the primordial mantle. This is, however,

of a profound geological significance. Erosion is active only where the rocks of the crust are situated above the sea level, because the sea, disregarding coast erosion and eventual corrosion, defends the crust against the attack of erosive forces. On the expanding earth, originally of a much smaller surface, the hydrosphere has completely enveloped the surface and the erosion could begin its activity only at the time the first peaks began to rise above the waters. Indeed on our earth, which is at least four billion years old, the oldest known sedimentogenic metamorphic rocks are no older than 3 to 3.5 billion years. This means that the first processes of erosion could have begun their destruction only 3 to 3.5 billion years ago. Beginning with this fact, A. Holmes attempted to determine the annual radius increase and found a value of 0.4 mm. per year (personal communication) in fair agreement with value founded on entirely different principles.

The same mechanism explains why the intensity of erosion is increasing in the course of the earth's history. Evidently, if the surface of the oceans decreases with time, there will be an ever increasing continental surface that falls prey to the destructive geological processes.

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SECTION OF CHEMICAL SCIENCES

FREE RADICALS IN IRRADIATED NYLON*

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In recent years there has been considerable interest in the subject of radiation effects on high polymers both from the viewpoint of basic scientific interest and potential industrial application. It is presently held that the reactions that occur are free-radical in nature and that the free radicals are produced by several processes.

Absorption of ionizing radiation can produce ions and also electronically excited molecules. In turn these ions can undergo a charge-neutralization reaction, leaving again an excited molecule. These excited species, produced by the direct absorption or the charge neutralization, can undergo homolytic bond rupture to produce free radicals. While in general the radiation interaction is pictured as a random process the final results observed suggest that certain bonds are broken preferentially and that bond strengths are an important factor.

The nature and fate of the free radicals involved are also affected by such factors as chemical structure of the basic material, crystallinity, temperature, and environment. The methods most generally employed in the study of these phenomena are infrared spectroscopy and electron spin-resonance spectroscopy.

Nylon has previously been investigated by a number of other research groups. Bevington[1] irradiated nylon filament and exposed it to acrylonitrile vapor and observed the formation of an acrylonitrile graft to the nylon. This grafting was attributed to reaction of acrylonitrile monomer with trapped free radicals in the nylon polymer: Zimmerman[2] studied irradiated nylon by infrared spectroscopy and found free-radical effects that decayed on storage at rates that were a function of the radiation exposure. It has also been reported that irradiation of nylon produced a paramagnetic species that decayed over a period of days from a four-peak spectra to a broad singlet.[3]

The present work deals with studies on low crystallinity nylon 6-filaments irradiated in a cobalt 60 gamma facility. The free radicals produced by the irradiation were then examined in a Varian V-4500 spectrometer and their behavior was followed under varying conditions of time and storage environment.

In the present work an initial five-peak spectra was observed that decayed rapidly in vacuum to a broad singlet of longer lifetime. This

* This paper was presented at a meeting of the Section on February 7, 1961.

singlet decayed by a second-order process, and the specific rate constant decreased with increased irradiation exposure. It was also found (FIGURE 1) that with increasing dose the character of the initial spectra changed from the five-peak spectra to the singlet.

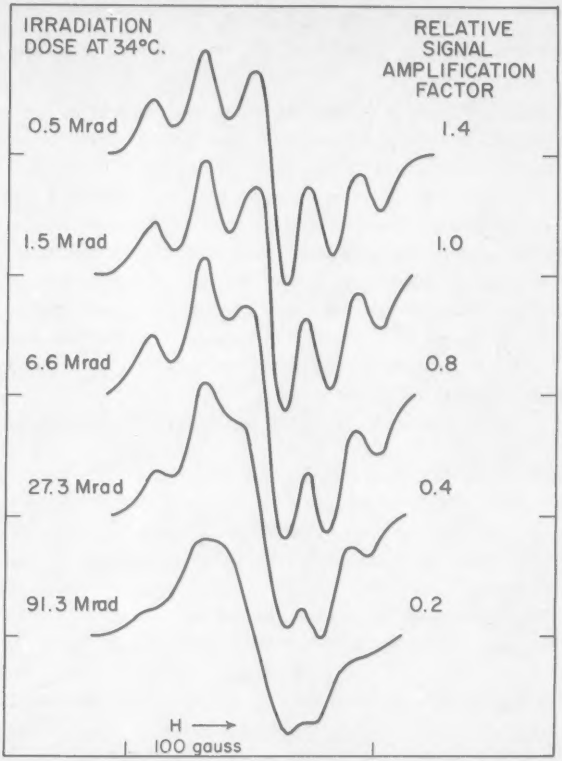

FIGURE 1. E.S.R. spectra of nylon-6 irradiated for various doses at 34° C. (spectra measured at liquid nitrogen temperature).

When the samples were permitted to decay in oxygen the decay rate was much more rapid, and there was no change in shape from the initially observed spectra. The decay under these conditions followed a first-order rate scheme.

The results are interpreted on the following basis. The irradiation is capable of producing radicals by a random bond rupture but these radicals are not fixed at their initial site of formation. They are capable of migration along the polymer chain by a process of hydrogen atom transfer but are stabilized or localized to some degree in the vicinity of the amide group because of resonance considerations. The five-peak spectra that

has been observed is attributed to a free radical on the amide nitrogen, the splitting being due to interaction with the nitrogen (spin 1) and the two equivalent protons on the alpha carbon. When a second free radical migrates to the vicinity of this first localized radical, a radical recombination occurs and a double bond is formed (FIGURE 2).

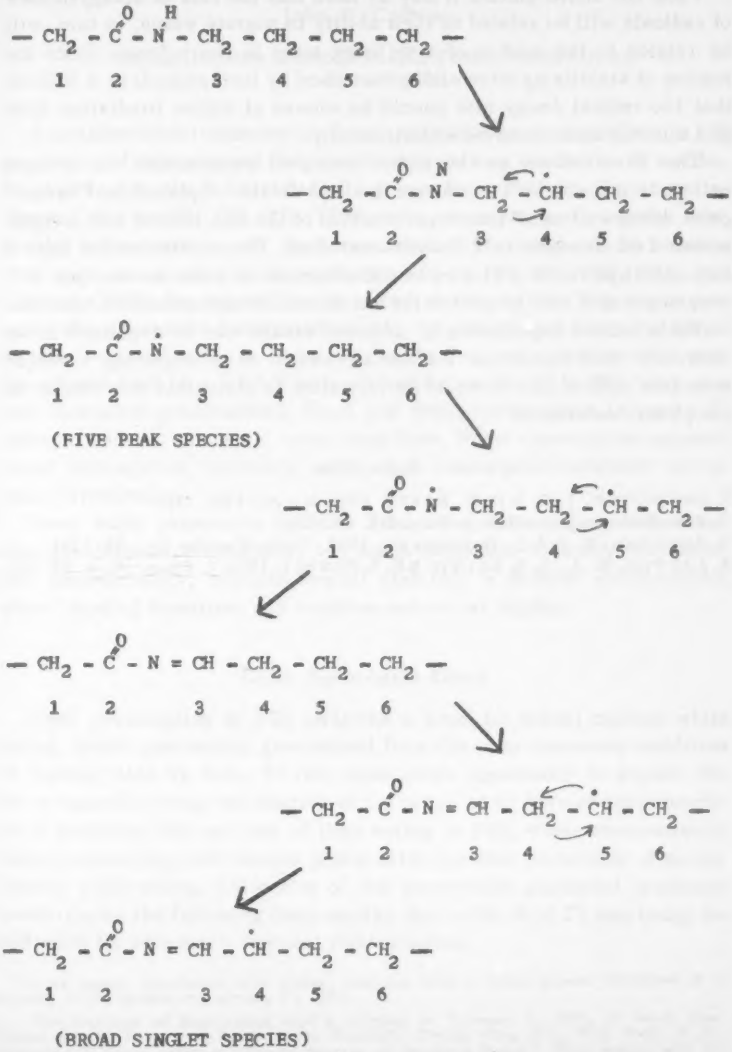

FIGURE 2. Free radicals in irradiated nylon.

The broad singlet is believed to arise from a free radical that migrates to carbon 4 after the double bond is formed. The unresolved character of this radical is attributed to the oscillation of the odd electron within the conjugated system. The broad singlet in polyethylene at high doses has been attributed to a similar action.[4]

From the above picture it may be seen that the rate of disappearance of radicals will be related to their ability to migrate which, in turn, will be related to the number of stabilizing sites in the polymer. Since the number of stabilizing sites will be increased by increasing dose it follows that the radical decay rate should be slower at higher irradiation dose and this has been observed experimentally.

The observations on the signal decay in oxygen, that is, a first-order rate process with no change in shape is also explainable. The first-order decay will result from rapid reaction of the free radical with oxygen whose concentration is diffusion-controlled. The transformation from a five-peak spectra to a singlet is not observed because the reaction with oxygen is rapid with respect to the mutual radical recombination reaction.

While all the experimentally observed results can be explained by an internally self-consistent mechanism based on a migrating hydrogen atom-free radical pair it would be premature to claim that this system is completely understood.

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SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

DETERMINANTS OF SOCIAL ORGANIZATION EXEMPLIFIED IN A SINGLE POPULATION OF DOMESTICATED RATS*

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A complex social organization developed within an enclosed (FIGURE 1) population of domesticated Osborne-Mendel rats was studied for 24 months. At peak density the N consisted of 3 generations of adults, designated as Tiers I, II, and III (TI, TII, TIII), born respectively during the first, fourth, and seventh month. Each consisted of 16 males and 16 females, 4 of each sex weaned in each of pens I to IV (PI, PII, PIII, PIV). See Calhoun (1961) for general trends of four such studies. This paper concerns the population designated as 1A. As pointed out there the height of the "burrows" and the endedness of the four-pen communication system should lead to a 3:4:3:2 ratio of density across PI to PIV when random movement predominates. Food and water consumption (FIGURE 2) reflects differential use of space over time. Water consumption approximated resting-time residency, while food consumption reflected active-period distribution.

Some major phenomena include: litter association effect; behavioral sink development; territoriality and harem formation; velocity, dominance, and homosexuality; maximum social stability; a delayed environmental effect; spatial desertion; and tradition and social rigidity.

Litter Association Effect

Food consumption in PIII reflected a need for social contact while eating, which presumably generalized from the prior customary condition of nursing side by side. TI rats upon given opportunity to explore the entire room following introduction of the ramps at 45 days of age, immediately exhibited 100 per cent of their eating in PIII, where environmental factors interacting with chance produced the greatest probability of social contact while eating. Extinction of this association proceeded to chance levels during the following three months due to the N of TI rats being insufficient for adequately frequent reinforcement.

*This paper, illustrated with slides, was the first of three papers presented at a meeting of the Section on February 13, 1961.

The Division of Engineering held a meeting on February 8, 1961, at which John Colton of the Processes Development Scientific Design Co., Inc., New York, N. Y. presented a paper entitled "Future Sources of Drinking Water." This article will be published in a subsequent issue of the *Transactions*.

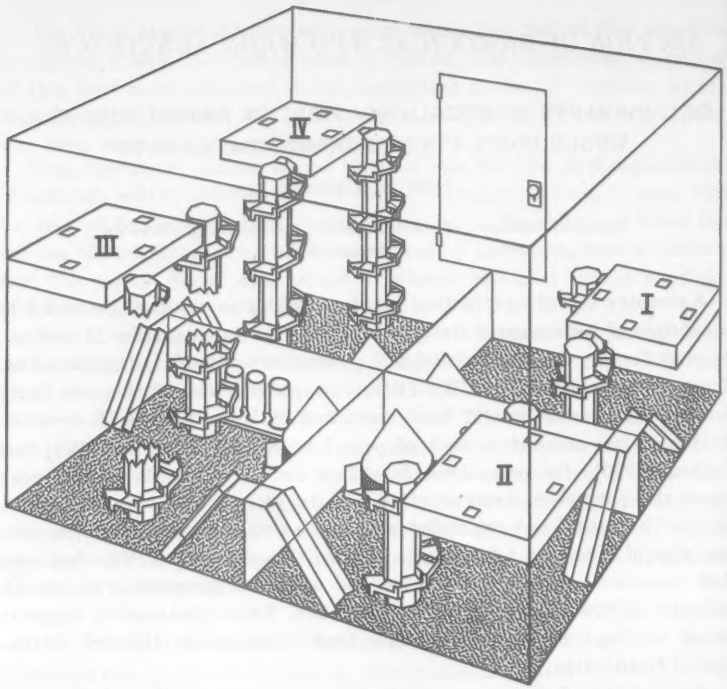

FIGURE 1. The habitat. Dimensions 10 × 14 × 9 feet. Partitions 24-in. high formed 4 pens, PI, PII, PIII, and PIV. The elevated square platforms connected to the floor by spiral staircases represent artificial "burrows." The 4-square openings on the surface of each provided access to a system of tunnels and nesting boxes. V-shaped ramps provided communication between PI and PII, PII and PIII, PIII and PIV. During the last few months of the study the ramp connecting PII and PIII was removed and placed by the door to the room, thus providing for the first time a direct connection between PI and PIV. At all times a superabundance of food in each pen was available from the conical topped hoppers. Similarly in each pen a superabundance of water was always available from a series of 2-quart bottles. A 3- by 5-ft. glass window on the roof of the room enabled observations of rats recognizable as individuals through coded spots of dye on the fur.

Behavioral Sink Development

When the N approached 96 rats following TIII weaning, opportunity for random contact while eating increased. Such contact predominated in PIII due to the bias of rats returning to PIII resulting from phenomenon No. 1 above. Gradually all rats conducted most of their eating (85 per cent of total by March 1959) in PIII regardless of their place of residence. I define as a "behavioral sink" this phenomenon of attraction to one locality to assure a conditioned social contact. It reflects a redefinition

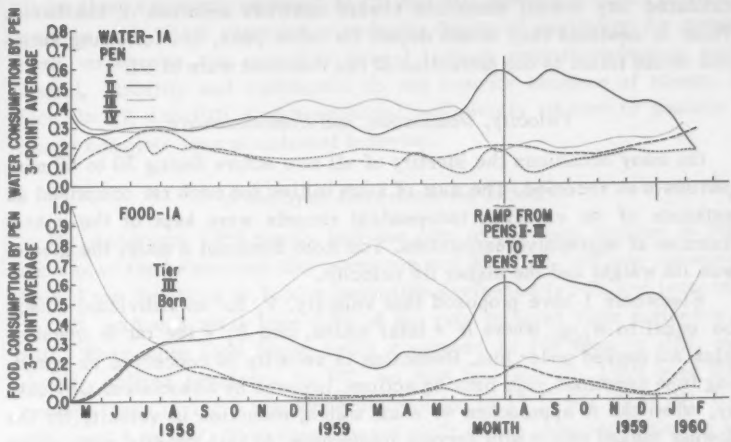

FIGURE 2. Food and water consumption. The total food and water consumed in each pen was recorded every two weeks. The absolute total for the room varied with the number of rats present. Therefore the curve for each pen was calculated from the proportion of the total consumed in all four pens for each of the 52 periods of observation.

of the act of eating as requiring social contact. Food consumption in PI and PIV reflects abandonment of areas where probability of social contact while eating was low.

Territoriality and Harem Formation

With most males away eating in PIII it frequently happened that only a fairly dominant male remained in PI or PIV. Upon their return, fights frequently occurred at the ramps leading into PI and PIV. Escape from conflict became associated with staying out of PI and PIV. Thus gradually one male in I and IV became territorial as a consequence of some rats having left to eat elsewhere rather than as a consequence of an initial expulsion. The lower burrow height in PI contributed to the ease of a male there becoming more strictly territorial since this enabled an increased probability of the remaining male encountering a returning male near the ramp. Complete territoriality never developed in PIV. At best, two males shared dominant status and never completely excluded other males. In PI the male excluded all or most other males for long periods. Females gravitated to this location of protection from sexual advances by other males. Their own interactions preserved the number of females here at 10 to 11 regardless of mortality or shifts in residence elsewhere. For all practical purposes from August 1958 to October 1959 only young born in PI survived to weaning. Elsewhere, unstable or stressful social conditions precluded survival to weaning. The territorial male in PI rarely

exhibited any sexual attraction toward oestrous members of his harem. While in oestrous they would depart for other pens, but following satiation would return to the protection of the dominant male of PI.

Velocity, Dominance, and Homosexuality

On many occasions the identity of all rats active during 30 to 60 min. periods was recorded. The sum of such tallies for each rat comprised an estimate of its velocity. Independent records were kept of the consequences of aggressive encounters. The more dominant a male, the greater was its weight and the higher its velocity.

Elsewhere I have proposed that velocity, V, for an individual should be equal to N_j/N, where N = total males, and N_j = the rat in question plus all ranked under him. Reduction in velocity is conceived as resulting from sanctions, role limiting actions, imposed by associates. Obviously, when the N approaches 40 adult males, reduction in velocity for the lowest ranked rats would become intolerable. At this density many males became homosexual, were mostly characterized by a low velocity, but were infrequently attacked by their dominant associates. Expression of homosexuality constitutes the development of another class outside the dominance hierarchy, in the same sense that juveniles and females form such a class. Members of all such classes, by avoiding sanctions from dominant males, maintain a less reduced velocity than would otherwise be the case. To the extent that creativity is a form of escape from imposed velocity reduction, homosexuality represents a form of creativity.

Maximum Social Stability

Stability is here considered in the sense of minimal change in residence, of threats instead of fights, and of persistence and recognition of status roles. Such a stability persisted from January through May 1959, the 9th through the 14th month of the study. Five surveys gave the following mean ratio of males to females by pen:

	Males		Females
PI	2.0	:	9.0
PII	10.8	:	10.3
PIII	22.7	:	10.2
PIV	7.2	:	5.3

PI: as discussed in the topic of Territoriality. PIV: here the most dominant male rarely descended to the floor to engage in fights with invaders. Instead this role became assumed by a much smaller male, toward whom other males responded as if his threats were those that could have been backed up by the actually dominant male. Even so, their combined efforts could never exclude all other males when the relatively few females

living there came into oestrous. In PII and PIII, despite a highly dominant male in each, there persisted a moderate degree of contention for status. Here no escape was possible except through velocity-reduction withdrawal. Stability and withdrawal do not connote absence of stress. In fact, in PII and PIII stress persisted sufficiently intense to produce a nearly complete loss of maternal behavior.

A Delayed Environmental Effect

By mid-March 1959 nearly half the rats in the room resided in PIII, yet due to the behavioral sink phenomenon 0.85 of all food was consumed here. From this time on, food consumption decreased in PIII and increased in PII, although until June 0.50 of the rats retained their residence in PIII. When more food began being consumed in PII than in PIII, rats rapidly shifted residence to PII, so that by July 23, 1959 over 0.60 resided there giving a residence distribution of 11 in PI; 38 in PII; 8 in PIII; and 4 in PIV. This long-delayed shift of the behavioral sink to PII is in line with the expectancy that the central position of this pen, coupled with its low burrow, favored rats arriving there. This shift disrupted established social relationships in PII and PIII and precipitated intense fighting among males, some of whom developed a bizarre tail biting that was equally expressed toward juveniles and females as well as other males.

Spatial Desertion

After the bulk of the rats left PIII for PII, the rats in PIV mostly shifted to PIII or PII, never to return to PIV. In this process it became quite apparent that shifts in residence primarily resulted from attractions toward a place rather than expulsion from a place by dominant rats. PIV became a "ghost town." For the final eight months of the study PIV remained deserted except for an occasional transient.

Tradition and Social Rigidity

On July 23, 1959, following maximum concentration of rats in PII, the ramp connecting PII with PIII was removed and replaced between PI and PIV. Were random movements still prevailing this would have lead to maximal numbers in PI and minimal in PIII. Nevertheless for three months the PI dominant male prevented any invasion by PII males, and the PIII rats remained isolated through their avoidance of the PIV "ghost town." By November 1959 the PI dominant male began to lose weight under the pressure of invading attempts by PII males. In response he gradually shifted residence to PIII. In so doing most of his harem followed him and rats resident in PIII prior to November 1959 mostly shifted over to PII. In this shifting, few rats stopped in PIV, although all had to pass through it.

On January 13, 1960 all females were removed. There ensued a rapid shift back to PIII (TABLE 1).

TABLE 1
DISTRIBUTION OF MALES

	January 13, 1960		February 24, 1960	
Pen	Observed	Expected	Observed	Expected
I	4	7.75	8	9.33
II	20	10.3	5	7.0
III	4	7.75	12	4.67
IV	3	5.15	2	7.0

This shift reflects a return to the ancestral place of attachment when current social inhibitory factors dissppear. These latter must have been represented by the harem in PIII, which served as a symbol for the presence of a dominant male, although in fact the former PI dominant male who had shifted to PIII had lost so much weight that he no longer possessed the prowess to exhibit dominant status. As already mentioned, this redistribution also reflects avoidance of PIV due to the "ghost town superstition."

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SOME EFFECTS OF LITTER SIZE ON SOCIAL BEHAVIOR IN LABORATORY RATS*

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The following study was designed to test whether the tendency for young rats to form feeding aggregations is influenced by the size of the litter in which individuals are raised. The observations of J. B. Calhoun (1961) suggest that such aggregative behavior has a profound influence on the ultimate structure and distribution of confined populations.

Equal numbers of Osborne-Mendel rats were cross-fostered and raised in litter sizes of 3, 6, and 12 in a series of 14 metal pens. When the 60 young rats were 36 to 44 days old, the parents were removed, alternate pen walls were removed, and the resulting 7 pens were connected in a a line by bridges (FIGURE 1). Following weaning, the probability of social contact while eating was varied in clinal fashion among the pens by providing an increasing number of metal partitions leading to the food (pellets behind wire mesh) in each pen. The highest probability of contact was in Pen I, the lowest in Pen VII. Food consumption was measured weekly and 100 observations of the location of each rat were made over a period of 165 days postweaning. Rats born to the experimentals were removed when found, maintaining a stationary population.

Despite having been reared in sizeable (3- by 4-foot) pens, many of the rats were slow to move out and explore the environment. While one half of the rats left the "home" pen by the second day after weaning, it was 54 days before all rats were known to have left the home pen. It took 30 days for one half of the rats to explore all 7 pens, and it was estimated that it would have taken 300 days for all rats to do likewise. This unexpected low velocity may have been due to the limited mobility prior to weaning: a situation that differed from the studies of Calhoun. Rats reared in small cages are very reluctant to move into strange environments. The low velocity obviously prevented many of the rats from learning the contact gradient; hence they were unable to select a situation that may have been more appropriate.

Despite the above weakness, there was a short period during which the rats approached a random distribution, followed by a period in which the rats were differentially distributed according to litter size (FIGURE 2). The 12s exhibited the highest contact index and the 3s the lowest, as anticipated. The maximum deviation related to litter size was achieved prior to the birth of the first young (about 50 days postweaning). Dis-

*This paper, illustrated with slides, was the second of three papers presented at a meeting of the Section of Biological and Medical Sciences on February 13, 1961.

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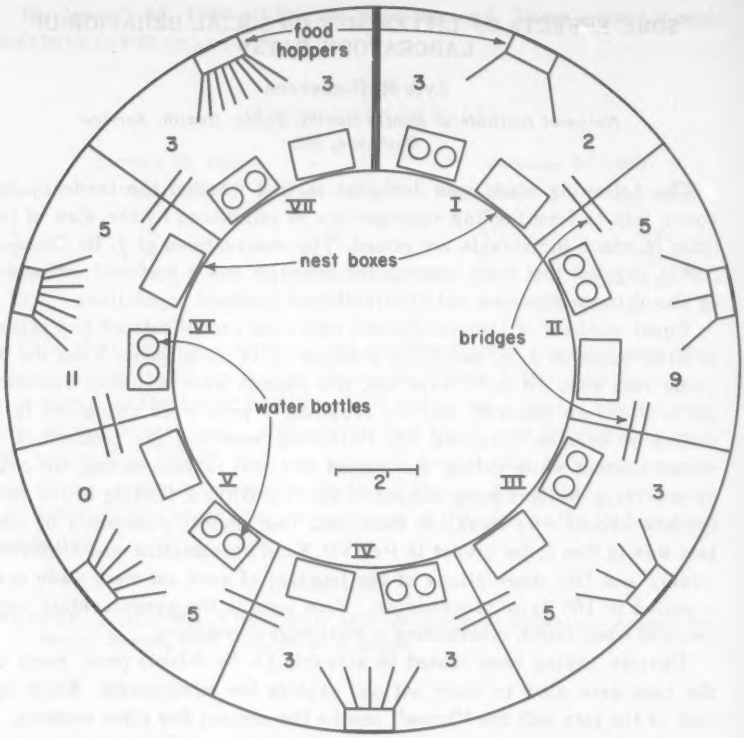

FIGURE 1. The experimental environment. Roman numerals are pen numbers. Arabic numerals indicate the number of rats weaned in each subsection of the pens.

tributions of all rats were then influenced by the parturient females defending pens and by the attraction of males for estrous females. Serious fighting among the males was evident about 90 days postweaning; thereafter, the relationships between litter size and the contact index were obscured.

The distributions of the rats varied with time, but the mean distribution of the males for the duration of the study approximated the expected, with the 12s most frequent in Pens I to III and least frequent in Pens V to VII. The reverse was true of the 3s, and the 6s were intermediate. The maximum probability of such a distribution occurring by chance is 0.037. The over-all distribution of the females, regardless of litter size, was skewed toward Pens I to III. Sex ratios here consistently favored females, while males were usually most prevalent in Pens IV and V.

Mean food consumption in Pens I to IV was initially equal to that in Pens V to VII; by the end of the study, twice as much food per pen was

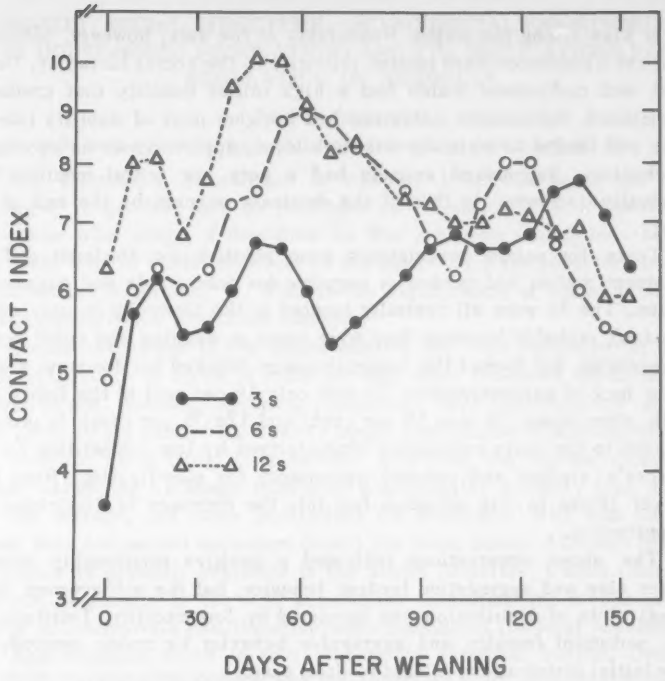

FIGURE 2. Temporal changes in the contact index (C.I.) by litter size (L).

$$C.\,I._L = \sum_I^{VII}\left(\frac{100\,N_o}{N_L} \cdot \frac{f}{F} \cdot \frac{1}{S}\right)$$

where I to VII are the individual pens; $\frac{100\,N_o}{N_L}$ the per cent of rats in a given litter size observed in the pen; $\frac{f}{F}$, the proportion of food consumed in the pen; and S the number of slots leading to the food in the pen.

eaten in I to IV as compared with V to VII. For most of the study, Pen II was the most heavily utilized pen, both in terms of residency and food consumption. Pen V was generally the least utilized. The number of rats feeding in Pens I to III, calculated from food consumption, exceeded the number sleeping there by an average of 2 rats for the duration of the study. In Pens VI and VII, an initial excess of 2-feeding rats gradually decreased to a deficit of nearly 4 rats that slept in these pens but fed elsewhere.

Generally, males were more mobile than females, exhibiting an average increase to an age of 160 days. Females increased markedly in mobility to an age of 75 days, and decreased progressively after the birth of the first litters. The detailed patterns of mobility varied significantly with

litter size among the males. Reanalysis of the data, however, indicated that the differences were related primarily to the social hierarchy. Dominant and codominant males had a high initial mobility that gradually diminished. Subordinate males reached a higher peak of mobility later in time and tended to maintain this high level, apparently as an avoidance mechanism. Suppressed animals had a very low initial mobility that gradually increased to that of the dominant animals by the end of the study.

Tests for paired associations were positive for dominant and codominant males, and random or negative for subordinate and suppressed males. The 3s were all centrally located in the hierarchy (mostly subordinates) probably because they were large at weaning and could not be suppressed, but lacked the aggressiveness required for dominant status. This lack of aggressiveness (3s won only 16 per cent of the fights with with other litters; 6s won 58 per cent; and 12s 75 per cent) is probably related to the early experience characterized by low competition for the mother's nipples and reduced opportunity for play-fighting. Rats from larger litters in this situation fell into the extremes of dominance and suppression.

The above observations indicated a positive relationship between litter size and aggregative feeding behavior, but the achievement of an ideal state of distribution was hampered by low mobility. Territorialism by parturient females and aggressive behavior by males overrode the the initial distributions related to litter size.

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DENSITY, SOCIAL STRUCTURE, AND NONSOCIAL ENVIRONMENT IN HOUSE-MOUSE POPULATIONS AND THE IMPLICATIONS FOR REGULATION OF NUMBERS*

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The information summarized in FIGURE 1 of this paper has been arranged in graphic form to facilitate consideration of four questions: (1) Over what range of densities do *Mus musculus* populations occur? (2) What kind of social structure is assumed? (3) What behaviors lead to such social structures? (4) What is the significance of social structure in the regulation of population numbers?

Across the center of the figure density has been indicated on a logarithmic scale in terms of mice per unit area. Observed densities are shown below. Naturally occurring populations have been reported only in the lower 10 per cent of the density range; populations inhabiting stacked or standing grain (field commensals) achieving the highest densities, those occupying buildings (domestic commensals) possibly less dense on the average, and those populations not associated with man but derived from commensal ancestors (feral) the least dense. Although the information is probably available in the Soviet literature, I have found no records of density in the wild populations inhabiting the steppe grasslands of central Asia and, therefore, have considered the feral populations as approximating those in this presumably ancestral habitat. Overlap between experimental populations and those occurring naturally is slight and is difficult to evaluate since effective density, in contrast to the absolute density (mice/unit area), may have been higher where simplified (not complexedly structured) experimental environments permitted maximum social interaction.

Correlation between density and social structure is shown by observations summarized above the density scale. Three types of social organization are suggested.

Mice of laboratory stock[3,24,25] and wild-caught stock[12,27,28] have been observed to form social hierarchies in which a single male dominates one or more additional males. The subordinates appear to be of more or less equal rank. Dominance is established through violent combat among sexually mature males. Under similar conditions females do not exhibit aggressive behavior, and they become involved in combat only when they happen to be in the path of aroused or contesting males.

"Togetherness" is the least well-documented social system. A domestic commensal population[33] and a field commensal population[16] are the basis of this category. Neither was the subject of detailed behavioral study, but in both cases a lack of evidence of aggressive behavior was

*This paper, illustrated with slides, was the third of three papers presented at a meeting of the Section of Biological and Medical Sciences on February 13, 1961.

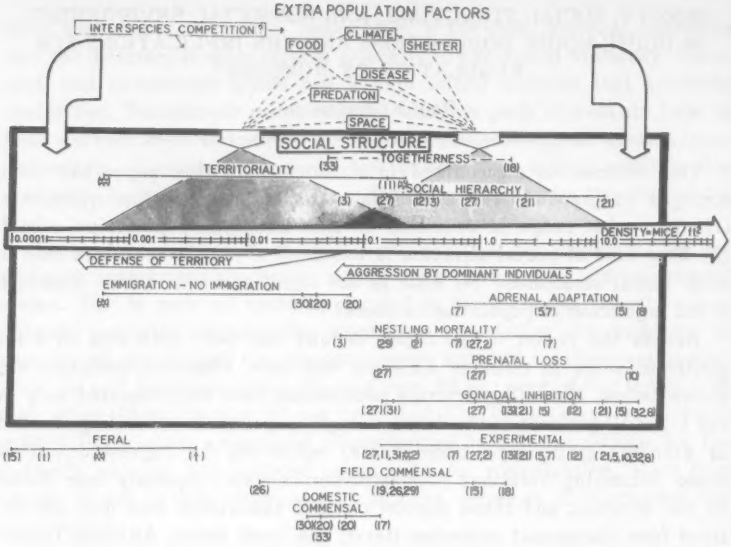

FIGURE 1. Relationships between habitat, density, social structure and density regulating factors in *Mus* populations. Density is shown on a logarithmic scale across the center. Numbers in parentheses refer to the bibliography. Density records for feral, domestic, and field commensal and experimental populations are given at the bottom of the figure. Within the heavy line indicating intrapopulation phenomena are shown records for social hierarchy and territoriality (*above density scale*) and for population responses tending to limit density (*below density scale*). Pathways for operation of extrapopulation factors are suggested at the top of the figure.

* Anderson, P. K. Unpublished data.

† Lidicker, W. Z. Unpublished data.

noted in association with high densities. This suggests that under certain circumstances aggressive behavior patterns may break down.

Territorial social organization in house mice conforms to both the broad definition of territoriality as occupancy of an area to the exclusion of other individuals of the same age and sex, and to the narrower definition of territory as a defended area. The literature contains one clear-cut observation[11] of territorial organization. In addition, I have found in a feral population (P. K. Anderson, unpublished data) that home ranges of mature males are almost wholly exclusive, and that ranges of mature females are largely so. Direct observation showed that most mature females aggressively defended their home ranges, but that tolerant associations of as many as five adult females were formed in especially favorable habitat. No instance of social contact between mature males was observed in this population, a fact that suggests that established males have little contact with each other at territory boundaries.

Davis[14] has suggested that the same pattern of individual behavior may lie at the root of both territorial and hierarchical social organization. This is a cogent argument, and information available permits suggestions regarding the course of events and the conditioning factors. It has been found in domestic mice that victory in combat is most likely for males that are in a familiar pen, are in the presence of familiar associates, have experience of prior victories, or are of larger size.[22,23,25] In a feral population young mice remain within the parental home range until puberty (P.K. Anderson, unpublished data), the time at which aggressive behavior has first been observed in mice of domestic stock.[24] In the feral population extensive wandering begins at this time, and social encounters with strange mice are probably frequent. Such encounters are most probable with larger and older, resident individuals. The latter enjoy the important advantages of previous experience of victory on familiar terrain, and successful establishment of the wanderers would appear likely only when unoccupied territory was reached. There the opportunity to establish familiarity with the terrain would make victory over later arrivals likely and territory could be established.

The development of social hierarchy seems likely to be the result of two changes in the situation described above: lack of opportunity to emigrate, and lack of escape cover. In the spatially complex environment of a feral population, and in spatially complex population cages, aggressive encounters only rarely involve physical contact (P. K. Anderson, unpublished data). The victim of an attack usually flees at the first rapid movement of the aggressor and is able to escape before the latter can close and complete his attack. Social dominance seems less likely to be achieved under these conditions. In respect to emigration, the instances of social hierarchy reported in the literature[5,12,21,27] have all involved confined populations. In such populations young mice would be vanquished in combat by established dominant males and become socially subordinate. Natural environments where social hierarchy should be looked for may be characterized as having abundant and highly localized food supplies, and sharp discontinuities between favorable and unfavorable habitat that might discourage emigration. The populations of stacks of grain (corn ricks) seem favorable for such social arrangements, although in such situations escape cover is abundant.

Where the opportunity for emigration exists an exodus seems to be the first response to crowding.[31] Therefore regulation of population density might occur through banishment of wanderers (P. K. Anderson, unpublished data) and social subordinates[4] to marginal environments where failure or delay in finding suitable breeding sites and mates would lower reproductive output and where vulnerability to predation, disease, or inclement weather would be high. The necessary corollary, inability of socially unestablished mice to penetrate established social units has been re-

ported.[20] It thus appears that under commonly encountered environmental conditions social mechanisms alone may control population density and, as indicated in the diagram these mechanisms tend to mediate the effects of extrapopulation factors. Calamitous environmental change (large arrows) can overcome the stabilizing effects of social structure and cause local or regional extinction. Conversely, extremely favorable conditions may cause the breakdown of the social mechanism and permit population explosions. In the extremely dense experimental populations commonly studied, other behavioral factors tending to regulate density (Cannibalism of young, nest destruction) and physiological maladjustments (abortion, resorption, gonadal inhibition, failure of lactation) have been reported. Such effects have been absent (for example adrenal adaptation in corn rick populations[29]) or observed rarely[29,30] under natural conditions. Gonadal inhibition, in particular, seems dependent on a degree of environmental and social stability not to be expected in the wild.[13,21] The conclusion suggested here, therefore, is that density regulation may involve such mechanisms only when the purely social factors prove inadequate. If such instances are as rare as the density records diagrammed here indicate, the gonadal-adrenal-pituitary relationship explored by Christian[5-9] would be involved only rarely, and its operation in population regulation may be abnormal or secondary to some other, undiscovered, primary function.

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DIVISION OF PSYCHOLOGY

AN EXPERIMENTAL ANALYSIS OF THE CRITICAL PERIOD FOR IMPRINTING*

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Introduction

Interest in the effects of early experience upon the behavior of adult animals has increased significantly in recent years as evidenced by investigations of problems ranging from the genesis of filial behavior in Aves to the development of tactile discrimination in Primates. In general, this increase in interest has been due to a growing awareness that analysis of the role of early experience is of fundamental importance in understanding many aspects of adult behavior. Witness the amount of research that has been concerned with the influence of neonatal sensory deprivation on functions, such as form discrimination, interocular transfer, and problem-solving capacity. Consider also the number of studies designed to investigate the relation between early social experience and the sexual and parental behavior of the adult organism.

Although these studies have called attention to the effects of variations in neonatal experience on the ontogeny of a wide variety of vertebrate response patterns, we still lack any clear understanding of the manner in which these effects are exerted (Beach and Jaynes, 1954). For example, which particular developmental processes are involved when the sensory environment of an animal is restricted so that it subsequently shows increased emotional excitement (Melzack and Thompson, 1956) as well as decreased responsiveness to pain? (Melzack and Scott, 1957). That early experience is influential in structuring adult behavior can scarcely be doubted, but the means by which this influence operates is, at best, only incompletely understood.

The results of a recent study by Fantz (1957) suggest that the desire for increased understanding of the manner in which intraorganic processes and extrinsic stimulus conditions interact in ontogeny can be served in

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The Division of Instrumentation held a meeting on February 14, 1961, at which Tom Haney, John Gerke, M. E. Madigan, and Joseph F. Pagano of The Squibb Institute for Medical Research, New Brunswick, N. J. and Andres Ferrari of Technicon Instruments Corporation, Research Park, Chauncey, N. Y., presented a paper on "Automation of the Microbiological Assays of Antibiotics with an Autoanalyzer Instrumental System." This paper will be published as an Annal of the Academy.

The Section of Physical Sciences held a meeting on February 15, 1961, at which Leon Zadoff of the Research Division, Republic Aircraft Corporation, Mineola, N. Y., presented a paper entitled "The Scattering of Electromagnetic Waves by a Metallic Strip and its Application to the Diffraction Pattern of the Echelette Grating." This paper will be published as an Annal of the Academy.

some cases more effectively by employing species-specific responses as indicators of this interaction rather than behavior established through instrumental conditioning. A species-specific pattern suitable in this respect would be one that occurs with predictable regularity very early in the life of the organism and that, although stereotyped in its expression, is nevertheless liable to modification by manipulation of the sensory environment. The phenomenon that Lorenz (1935) designated as "imprinting" appears to meet these requirements.

It is the purpose of this paper to discuss a recent attempt to study experimentally one singular feature of this phenomenon, that is, the age at which imprinting is effective.

Some Definitions of Imprinting

In 1873 Spalding reported that incubator-hatched chicks tended to follow persistently the first moving object to which they were exposed. Heinroth (1910) subsequently called attention to this when he reported that graylag geese can be made to respond to humans in filial fashion in preference to adults of their own species if they are exposed to humans just after hatching. Several years later, Lorenz (1935), concerned with analyzing the functional significance of stimuli involved in releasing and directing the social behavior of birds, extended the empirical basis of Heinroth's observations and provided a theoretical framework within which to interpret these observations. Lorenz emphasized that in certain species of birds a wide variety of either animate or inanimate objects can acquire, in the absence of any conventional reinforcing agent, the capacity to evoke certain aspects of behavior that are ordinarily directed toward members of the species.

Since the conditions under which an object can acquire this capacity and the characteristics of the behavior thus evoked were considered unique, Lorenz designated the process or mechanism involved by a special term: imprinting. To distinguish imprinting from associative learning, he emphasized the following aspects of the imprinting process:

(1). Imprinting can occur during a very definite period of the animal's life; a period of short duration during which the organism is assumed to be in a critical stage of physiological development. Thus if a graylag gosling, for example, is to respond to a human (or any other relatively large moving object) in filial fashion, initial exposure to the human must occur within several hours after hatching. The effect of this exposure is at first shown by the fact that the gosling persistently follows its "surrogate parent."

(2). Once imprinting occurs its effect is irreversible. That is, the stimulus to which the animal is exposed during the brief critical period henceforth becomes either the preferred stimulus or the only stimulus

toward which the following response will be directed. This preference, once it is established, remains extremely stable presumably throughout the life of the animal. Thus with reference to graylag geese, Lorenz (1957) states: "Once their instinctive social reactions are transposed to a human being, their behavior does not change in the least even if they are kept for years with other members of their own species and without human company" (p. 105). Although this statement is perhaps too extreme to be taken as representative of Lorenz' views on the question of stability, there is no doubt that he believed imprinting produces modifications in behavior that were extraordinarily resistant to change.

(3). Lorenz pointed out that many aspects of adult behavior that are not functional in the neonatal period during which imprinting is operative will nevertheless be directed toward the "imprinted object" when functional status is subsequently achieved. The fact that exposure to an object early in ontogeny can influence, in so specific a fashion, as-yet-undeveloped response patterns was considered characteristic of the imprinting process. Lorenz cited the case of adult shell parakeets that directed their courtship activities toward humans in preference to available members of the species as a consequence of their having been "Imprinted" to humans. This aberrant sexual behavior was held to be the result of imprinting and not of conditioning since, as Lorenz maintained, " ... you cannot condition any not-yet-functioning response in the ordinary way" (1955, p. 209).

(4). When a bird becomes "imprinted" to a particular stimulus, it will readily transfer its following response as well as other social responses to all members of the class to which that stimulus belongs. In other words, imprinting was assumed to result in attachment not to the specific features of an object but to its general characteristics. Thus when a gosling, for example, is hatched under a muscovy duck, it subsequently follows not only its particular "foster parent" but all members of the species to which its "parent" belongs. Lorenz conceived of imprinting (as it operates in nature) as a method of acquiring a "consciousness of species," thereby insuring that social behavior will extend beyond the species.

Although it is obvious that Lorenz considered imprinting to be capable of influencing a variety of behavior patterns, all attempts to study the imprinting phenomenon systematically have focused on the following response. This paper will also deal with this specific response and, in addition, will use the term imprinting to denote a particular experimental operation and not a process or a mechanism. Thus imprinting will be defined as the procedure of visually presenting to an animal a large moving object during the first several hours of its life under conditions that insure that the object is not associated with such conventional reinforcing agents as food and water. This procedure has been found to

evoke a close following of the object in such precocial avian species as ducks, geese, coots, moorhens, and domestic fowl.

Evidence Attesting to the Critical Period

One reason that imprinting has generated so much interest is that the effectiveness of the procedure appears to be restricted to a specific period of development. It will be recalled that Lorenz maintained that if an object is subsequently to elicit following, *initial* exposure to that object must occur within a relatively brief period after hatching; a period during which the bird is assumed to be in a critical stage of physiological development. Recently several investigators have attempted to obtain evidence regarding the range of the critical period. For example, Fabricius (1951) reports that in tufted ducks following can be elicited only if initial exposure occurs before 12 hours of age while, in the mallard, readiness to follow a strange moving object was still apparent in some cases after exposure was delayed as long as 72 hours. Even in the mallard, however, the probability of the animal following a strange object was found to be inversely related to the age at which initial exposure occurred. Alley and Boyd (1950) have shown that imprinting for the coot is most likely to prove effective if it is administered within the first 8 hours from the occurrence of hatching. Ramsey and Hess (1954) found that for both mallard ducklings and Bantam chicks, 13 to 16 hours after hatching appeared to constitute the critical period. They reported that as little as 10 min. of exposure to a male-model decoy during this time was sufficient to produce a strong approach response in a subsequent choice test that involved the familiar model and an unfamiliar female decoy. The incidence of "correct" choices was found to decrease sharply when initial exposure occurred either before 13 hours or after 16 hours. FIGURE 1, reproduced from Hess (1957), reveals the magnitude of this decrement.

I have found that in the Peking duck the critical period extends from about 8 hours to about 16 hours after hatching. Gottlieb (1960) has recently presented data suggesting that the critical period characteristic of this species can be more sharply circumscribed if chronological age is calculated from the onset of incubation rather than from the termination of hatching. This result is not surprising; hatching is initiated in part by random mechanical factors (Kuo, 1932) and consequently can be expected to provide a less stable baseline than onset of incubation.

Patterned-Light Experience as a Determinant of the Critical Period

On the basis of the evidence we have reviewed, there can be little doubt that there is a brief period in the ontogeny of precocial birds during which imprinting is most likely to induce following. The question that arises now, of course, is what are the conditions determining the occurrence of

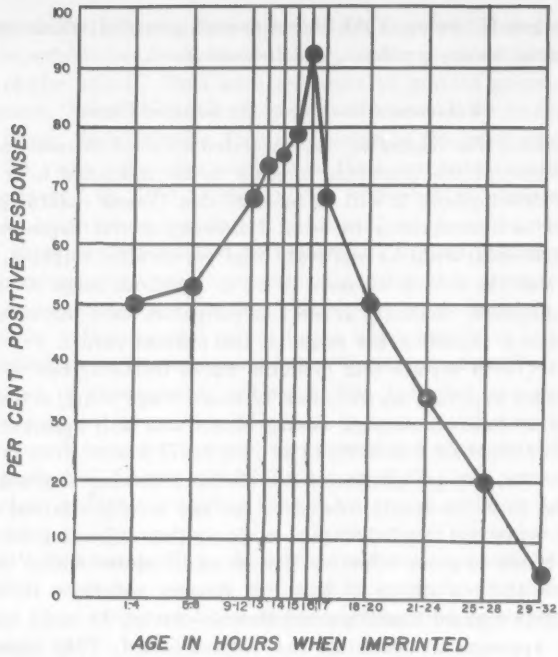

FIGURE 1. Critical age for imprinting in mallards expressed as the per cent of positive responses. (Hess, 1957).

this period. Two very general answers have been offered. On the one hand, Lorenz (1937), Hess (1959), Gottlieb (1960), and others have implied that the critical period is the direct result of a highly invariant sequence of maturational events which, as Hess states, "...has a counterpart in any of the innate responses at a reflexive or tropistic level" (p. 76). On the other hand, Moltz (1960) and Schneirla (1959) have suggested that the bird's readiness to respond to a moving object at one particular stage of its ontogeny and its lack of responsiveness when initial exposure occurs at a later stage is the result of changes brought about through the progressive interaction between the developing organism and its sensory environment.

Although these suggestions have not, of course, been formulated with sufficient precision to support a crucial experimental test, they do provide different points of departure with respect to studying the critical period. Thus in accord with the "interaction viewpoint" one might begin by focusing experimental attention on the bird's early sensory environment with an attempt to manipulate that environment in a manner calculated to vary the age of imprinting effectiveness. A reasonable assump-

tion would be that the animal's experience with patterned light – and thus its experience with visual forms – very early in ontogeny might function as an important determinant of the critical period. Indeed, even if the patterned-light environment were to contain no moving objects, the very presence of a structured or articulated perceptual environment might conceivably influence the animal's subsequent behavior toward the imprinting object. Of relevance is the frequently reported observation that when initial exposure to the imprinting situation occurs after the critical period, the bird exhibits diffuse emotional excitement that presumably results in responses incompatible with following. Indeed, Hinde (1955) has suggested that the critical period is not the result of an inferred imprinting process but a consequence of the appearance of such conflicting response tendencies. Also of relevance are the results of recent studies (Hebb, 1946; McBride and Hebb, 1948; Melzack, 1952) on the genesis of emotional behavior in several vertebrate species indicating that strong fear can frequently be elicited by strange but innocuous visual stimuli in the absence of specific avoidance conditioning. On this basis, it seemed reasonable to assume that the emotional excitement exhibited by a bird past the optimal age for imprinting occurs in response to the unfamiliar visual stimuli provided by the imprinting situation. Perhaps the time during which it was exposed to the structured sensory environment of the cage served to establish the visually "familiar" and, by thus rendering the test object and the apparatus "unfamiliar," contributed to the arousal of emotional responses imcompatible with following and consequently reduced imprinting effectiveness. It would follow from this that the more perceptually naive *S* is at the time of initial introduction to the imprinting situation, the less likely it would be to display fear, and the more likely it would be to pursue the test object. On this basis it does not seem unreasonable to suggest that the critical period for imprinting might be significantly extended if the bird's early visual experiences in the cage were restricted. An experiment performed at Brooklyn College by L. Jay Stettner and myself was designed in accord with this suggestion. I should like to discuss that experiment in detail.

Apparatus

The apparatus consisted of an unpainted wooden alley 10 ft. by 2 ft. by 2 ft. Contained in the alley was a leather belt that passed around two pulleys set 9 ft. apart. A green cardboard object was suspended from the belt and made to travel down one side of the alley and up the other. A motor drove the pulleys and was adjusted so that the object moved at a constant speed of 0.4 ft./sec. Four Standard Electric Timers were used to record the number of seconds that *S* spent following the object. FIGURE 2 shows a sketch of the apparatus.

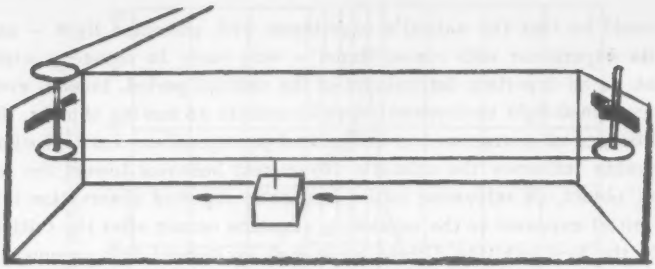

FIGURE 2. Apparatus for study of filial imprinting in ducklings.

Procedure

The Ss were 72 Peking ducks hatched in a forced-air incubator in the laboratory. Each S was removed from the incubator within approximately 4 hours after hatching and assigned either to an experimental or to a control treatment. Each experimental S had a latex hood placed over its head, the hood fashioned so that it did not press against the corneas and did not hinder the bill from opening and closing freely. The transmission characteristics of the latex allowed the retinas of the ducklings to be stimulated by brightness differences but prevented the perception of visual forms. Each control S was also fitted with a hood but one in which a hole had been cut in either side permitting normal patterned-light stimulation.

The experimental and control groups were further divided into four subgroups henceforth designated as the 12-, 24-, 48-, and 72-hour subgroups respectively. The subgroup designations indicate the mean age at which the first imprinting trial was administered. Thus an S assigned to a 48-hour subgroup, for example, was kept in its cage under the diffuse-light condition imposed by the experimental treatment (E-48) or under the patterned-light condition imposed by the control treatment (C-48) until it was approximately 48 hours old, at which time the hood was removed and S was placed in the imprinting apparatus for the start of the first imprinting trial. Subgroups E-12 and C-12 each contained 12 Ss; the additional 48 Ss were evenly distributed among the 6 remaining subgroups As a matter of convenience, the age at which initial exposure occurred will henceforth be referred to as the "exposure age".

Each S was given two imprinting trials, the second trial being administered 24 hours after the first. An imprinting trial consisted of a 25-min. period in the presence of the test object. The pattern of progression that the object described was as follows: 10-min., moving; 5-min., stationary; 10-min., moving. At the termination of the first trial, S was taken from the alley and returned to its home cage. Its hood was not replaced, so that irrespective of subgroup membership, all Ss received patterned-light stimulation during the intertrial period.

Scoring

Previous results indicated that "attachment" to the object included not only following behind when the object was in motion, but also walking by the side of the object and frequently running ahead and then stopping to wait. A scoring procedure that appeared to reflect adequately these responses (such responses henceforth being designated as "following") involved activating the timer whenever *S* was either following the object within a distance of 1 ft. or was standing within a distance of 6 in. of any side of the object. For convenience, the number of seconds accumulated during the 20 min. that the object was in motion during a trial will be referred as a "following-score". In addition to the scores, protocols of the animals' behavior were recorded for each trial.

Results

The following score of each *S* was determined by averaging the scores obtained during the two imprinting trials. FIGURE 3 shows the median of these scores for each subgroup.

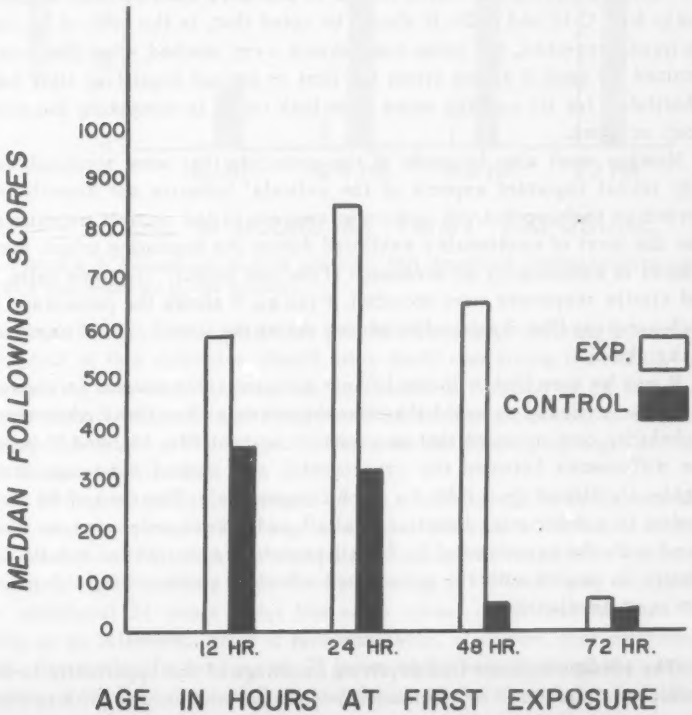

FIGURE 3. Median scores for each subgroup.

Inspection of this figure reveals that the experimental and control subgroups were nearly equivalent with respect to strength of following when first exposure to the test object occurred at 12 hours of age but were markedly different when first exposure occurred at either 24 or 48 hours. Indeed, an exposure age of 48 hours resulted in the control subgroup showing little following, while the same exposure age resulted in the experimental subgroup showing as much following as that exhibited by experimental *Ss* run during the critical period (that is, at 12 hours). However, when an exposure age of 72 hours was employed, the level of following attained by the experimental subgroup was almost equivalent to the level attained by its control counterpart.

In accord with the interpretation of FIGURE 3, no significant difference was found between the 12-hour subgroups ($U = 62$; $p > 0.50$) or between the 72-hour subgroups ($U = 25$; $p > 0.25$), but a highly significant difference was found between the 24-hour subgroups ($U = 10$; $p = 0.01$) and between the 48-hour subgroups ($U = 2$; $p < 0.01$). None of the differences among E-12, E-24, and E-48 was significant. Comparisons among the control subgroups revealed that C-48 and C-72 each differed significantly from C-12 and C-24. It should be noted that, in the case of all the analyses presented, the same conclusions were reached when the score obtained by each *S* during either the first or second imprinting trial was substituted for its average score over both trials in computing the subgroup medians.

Mention must also be made of the protocols that were recorded, for they reveal important aspects of the animals' behavior not directly reflected in their scores. Of particular concern in the present experiment was the level of emotionality exhibited during the imprinting trials. Such indices of emotionality as avoidance of the test object, "distress calls," and startle responses were recorded. FIGURE 4 shows the percentage in each subgroup that displayed avoidance during the first 5 min. of exposure to the object.

It may be seen that, with the 12-hour subgroups, the control *Ss* showed a greater tendency to avoid than the experimental *Ss*. The Fisher exact probability test revealed that at exposure ages of 24-, 48-, and 72-hours the differences between the experimental and control subgroups were highly significant ($p < 0.02$ for each comparison). The control *Ss* also tended to exhibit more "distress calls" and startle responses as compared with the experimental *Ss* for all periods of time. These results are clearly in accord with the anticipated effect of patterned-light deprivation upon emotionality.

Discussion

The results indicate that depriving ducklings of the opportunity to experience a structured or articulated perceptual environment prior to their being exposed to the imprinting situation significantly extends the age

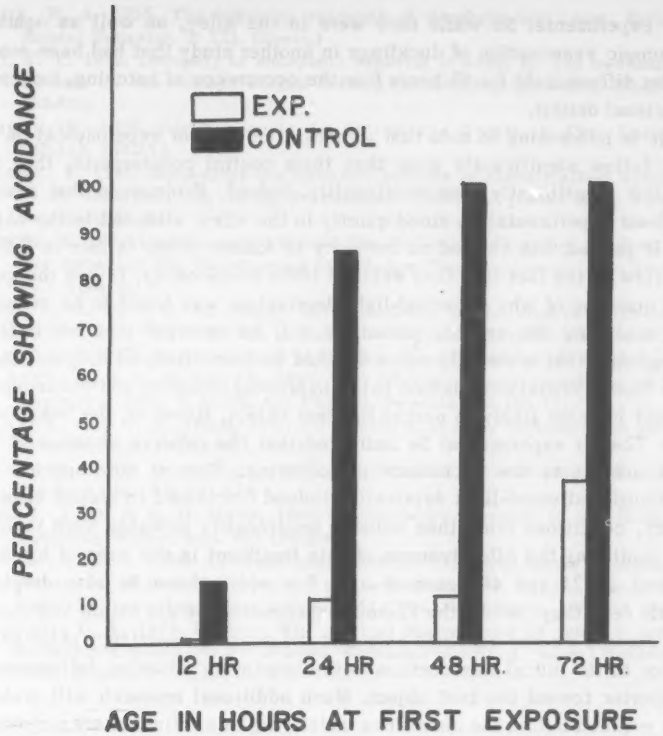

FIGURE 4. Percentage in each subgroup that displayed avoidance during the first 5 min. exposure to the object.

at which the imprinting procedure proves effective in inducing following. The fact of this extension should raise doubt concerning the validity of conceiving the critical period as an exclusive function of an invariant maturational sequence and should emphasize the importance of investigating the nature of the interaction between the developing organism and its sensory environment.

A finding of particular interest in the present study is that those experimental Ss whose initial imprinting trial occurred at 72 hours of age did not follow. Although patterned-light deprivation resulted in vigorous pursuit of the test object when an exposure age of 48 hours was employed, an additional 24 hours under the same visual conditions resulted in little or no following. While it is conceivable, of course, that patterned-light deprivation for as long as 72 hours might have damaged the visual system of the bird, it is unlikely that failure to follow was due to failure to perceive the test object adequately. Observations of the behavior of

the experimental Ss while they were in the alley, as well as ophthalmoscopic examination of ducklings in another study that had been reared under diffuse light for 65 hours from the occurrence of hatching, indicated no visual deficit.

It is interesting to note that although the 72 hour experimental Ss did not follow significantly more than their control counterparts, they did exhibit significantly less emotionality. Indeed, *E* observed that several 72 hour experimental Ss stood quietly in the alley, attended to the object as it passed, but showed no tendency to follow. Their failure to follow, in view of the fact that they evinced little emotionality, raises the general question of why patterned-light deprivation was found to be effective in extending the critical period. It will be recalled that we initially suggested that a visually naive *S* would be less likely to display fear at the time of initial introduction to the imprinting situation and consequently would be more likely to pursue the test object. However, the behavior of the 72-hour experimental Ss indicated that the relative absence of fear did not insure the occurrence of following. Thus it now appears that although patterned-light deprivation indeed functioned to reduce emotionality, conditions other than reduced emotionality probably were involved in mediating the effectiveness of this treatment in the case of birds exposed at 24 and 48 hours of age. For while these Ss also displayed little fear, they, unlike the 72-hour experimental Ss did follow vigorously. At present we can conclude only that the sensory experience of the animal prior to its initial introduction to the imprinting situation influences its behavior toward the test object. Much additional research will probably be required before the conditions underlying this influence are understood.

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DIVISION OF ANTHROPOLOGY

THE STATE OF AFRICAN MUSIC IN THE FEDERATION OF RHODESIA AND NYASALAND*

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The sudden emergence of African states into the community of the United Nations and the intense political and social unrest that has activated their drive toward nationalism have focused the attention of the world on this vast continent and its diverse peoples. It is timely, therefore, to examine one element of the native culture in its rapidly changing social setting to see what information it may give us regarding the thinking and feelings of the Africans today. For this study I have chosen music, a medium through which the African expresses himself as spontaneously and explicitly as through language. The African peoples are richly endowed musically and have developed a sophisticated and artistic musical culture that only now is beginning to attract the attention of music lovers and serious study by ethnomusicologists. Although the data of this research and the conclusions they suggest are limited to the Federation of Rhodesia and Nyasaland, I believe that the approach to the study of a changing culture through music may prove valid and useful in other areas.

In 1953 the self-governing British Crown Colony of Southern Rhodesia and the two British Protectorates of Northern Rhodesia and Nyasaland were joined in a federation with a federal government charged with the responsibility "for defense, external affairs, transport and communications, immigration, customs and excise, currency, health, education (except the primary and secondary education of Africans), European agriculture in Southern and Northern Rhodesia and certain important economic functions necessary to co-ordinate the economic life of the country." [1]

Extending over a land area of 489,330 square miles, larger than the combined area of Texas, California, and New York, the federation has a total population of 7,887,000, composed of 7,560,000 Africans, 292,000 Europeans and 35,000 Asians, Coloreds and persons of other classification. Although Christian missions have been active in a limited way since the middle of the last century, colonization did not begin until 1890,

*This paper, illustrated with slides, was presented at a meeting of the Division on February 27, 1961.

The Division of Microbiology held a meeting on February 24, 1961, at which Vincent P. Girillo of the Department of Microbiology, Seton Hall College of Medicine and Dentistry, Jersey City, N. J., presented a paper entitled "The Mechanism of Sugar Transport into the Yeast Cell." This paper will not be published by the Academy.

The Division of Biochemistry held a meeting on February 28, 1961, at which Irwin H. Mossbach of Columbia University Research Service, Goldwater Memorial Hospital, Welfare Island, N. Y., presented a paper entitled "Hormonal Effects on Sterol Metabolism." This paper will not be published by the Academy.

when John Cecil Rhodes and his Pioneer Column occupied Mashonaland, the eastern part of Southern Rhodesia. Since then there has been a slow but steady infiltration of settlers fron Great Britain and Afrikaaners from the Union of South Africa, a movement greatly accelerated after World War II. The rich resources of the land and its potential have drawn immigrants who found here greater opportunities for improving their economic and social status than in their homeland. While cattle ranching and the cultivation of such crops as maize, peanuts, tobacco, cotton sorghum, millet, and tea has been an important source of income, it is the mineral wealth of copper, gold, asbestos, chrome, lead, and zinc that outweighs other resources of the country. Since the war there has been a rapid industrial development in the manufacturing and processing of steel, textiles, and rubber.

This historical and economic information may seem irrelevant to the subject of this paper but it is of the utmost importance toward an understanding of African music, for it is in the social environment created by these historical and economic factors that the African makes his music today. As a natural and spontaneous expression of the daily living of the African, music reflects his thoughts and feelings about those events and situations that are of immediate concern to him. Unlike the art music of the West, African music is not limited and bound by notation. It is a folk music that takes its form in improvisation and is subject to variation with each re-creation as it is perpetuated through oral transmission, a dynamic, vital folk art that offers insights into the inner life of the people.

The cessation of tribal warfare and raids following the European colonization, and the lengthening of the average life span through medical care and health service have resulted in a steadily increasing population. In Southern Rhodesia the Land Apportionment Act of 1941, superseding the original Act of 1930, divided the land between whites and blacks, leaving the Africans less than half of the land, and the Native Husbandry Act of 1951 provided for individual holdings of arable land that could not be subdivided. The limitations imposed by these acts have forced the young generation, male and female, to seek employment in the urban centers. In Northern Rhodesia the mines of the Copper Belt have acted as a magnet to draw able-bodied men from the land into their employ. In Nyasaland, where the density of population is 55.3 persons per square mile, it is estimated that at any given moment there are between 150,000 and 200,000 Nyasaland men out of the country working for their living, about two thirds of them in Southern Rhodesia.

What, we ask, do these facts mean in relation to African music? They mean that there is scarcely an African who has not been in contact with Western culture either directly or indirectly, and that through this contact he and his culture have been consciously or unconsciously affected. In discussing the contemporary music it would be somewhat easier if one

could make two neat categories, one to include the traditional music of the reserves and rural areas, the other to include the music of urban centers. However, the cleavage between these two classifications is not a clear one, for there is a constant exchange between these two groups. Although the African population in the urban centers is becoming more permanent through home ownership and steady employment, the urban worker and his family are still deeply rooted in the reserve through family relationships, tribal affiliations, and an intangible but nonetheless real attachment to the land. The bachelor urban worker is less permanent and is apt to return to the reserve after having saved enough money to pay his taxes and purchase some of the European goods that are not available to him in the reserve. With the changing economy the African's wants have changed. Articles once regarded as luxuries are now regarded as necessities. On his return to the rural areas the African brings with him not only the radio, the phonograph, and commercial records of urban African music but also the ideas, political and social, that he has acquired through his association with urban Africans from other tribes and with European employers. This does not mean, however, that the traditional music is dead or that all of it is influenced by the urban music. It is too deeply rooted in the psyche of the people to become extinct in such a short time. However, with the accelerated rate of culture change it would be foolish to predict the future of African music.

There is at present a tendency among Africans, both educated and uneducated, to turn their backs on things African and to adopt the accoutrements of Western European culture. In Bulawayo, Southern Rhodesia, where much of my work was done, this trend was glaringly evident. At the African public dances in Stanley Hall contests were held and prizes awarded for the best ballroom dancing and the best-dressed man and woman, the winners looking like mannequins that had stepped out of the display windows of the European stores. At the same time the raging spirit of nationalism and Africanism has led the African to an awareness of the significance of his culture. Just as the Oxford-educated African diplomat dons the tribal dress of his people to declare his nationality and Africanism, so may the people act to perpetuate their traditional musical culture as a means of identification and self-expression. Which of these contradictory, polar trends will dominate and direct the future musical culture of Africa? Perhaps neither one, for I believe that their coexistence is possible.

With the industrialization and urbanization of Africa and the attendant detribalization, it is most likely that much of the traditional music will lose its functional meaning. However, it is possible that it will be preserved as a cultural survival of an historic past. The belated salvage of the indigenous folk songs and ballads of the British Isles and their popular revival is to be credited to Cecil Sharp and to the English Folk Song Society, which recognized the cultural value of this music before it became extinct. Through similar organizations and institutions Africans may

succeed in keeping alive their traditional music. At a Sunday afternoon meeting of the Shona Mutual Benefit Society in Bulawayo, I witnessed and recorded the re-enactment of a village scene and ceremony that was staged not for me, but for the entertainment and pleasure of the members. On another Sunday afternoon I attended a special service of the Mzilikazi Baptist Mission Church in Bulawayo in which the daily life of the kraal was presented with singing and dancing. In the government African schools dramatizations of native life are staged, and at the Bulawayo Eisteddfod, an annual song festival and contest that lasts one week, instituted and organized by Europeans for Africans, native songs and dances are performed with a spirit and style that indicate that the tradition is a living one, still fraught with emotion and meaning for the African youth.

The perpetuation of traditional music does not preclude change and the development of a new music. The most distinguishing characteristic features of African music are dynamism and vitality, overt expressions of psychical forces are physical energy that account for its great abundance and variety. One can safely assume that these forces will continue to operate in the making of music, but music lovers with an appreciation for the diverse and unique music cultures of the world's peoples hope that the African will build his new music on the solid foundation of his indigenous musical culture and not capitulate to the world-wide invasion of Western popular music.

In the rural areas traditional music is still practiced in its functional setting. Rain-making ceremonies, divination, marriage, death and funeral rites, and the *bona* ceremony conducted to honor and satisfy the spirit of the deceased are all accompanied by music. Folktales interspersed with songs, the *cante fable*, children's singing games, and a variety of social dances provide entertainment during the long evenings. Older women lighten their work of stomping and grinding cereals with appropiate songs.

In the cities the modern African music known as jive holds priority over traditional music. Played by an orchestra of modern instruments, saxophone, electrically amplified guitar, bass viol and drums, this music is heard in the dance halls and at the Jive Klub (sic), an outdoor dance plaza operated on Saturday and Sunday afternoons by the African Administration of the Municipality of Bulawayo as part of the Welfare and Recreation Program. Commercial phonograph records, emanating for the most part from Johannesburg, and broadcasts from the Federal Broadcasting Station in Lusaka, Northern Rhodesia, give wide distribution to this music, not only in the urban areas but also in the reserves.

The early missionaries lost no time in translating their Christian hymns into the African languages and teaching them to their converts. However, in fitting the translated texts to the European tunes they failed to take into account the tonal character of the native languages. Syllables of high pitch were mated with low tones in the melodic lines of the hymns and vice versa, thereby destroying the meaning of the words. The result

was a gibberish that the African accepted as part of the mysterious ritual of the new religion. Today these European hymns with their distorted texts are so deeply imbedded in the affections and emotions of the older African Christians that there is strong opposition to any attempt to develop a new African hymnology. Despite this opposition promising experiments are being made in adapting African melodies to the Christian church service. Henry Weman's book, *African Music and the Church in Africa,* [2] has guided the Swedish missions in an enlightened approach to this problem. In 1960 the Methodist Mission Board detailed a former student of mine to work in Southern Rhodesia with special emphasis on the development of indigenous music in the church. It is too early to evaluate the results of this work.

African children love to sing, and music constitutes an important subject in the school curriculum. An amazing amount of traditional music is to be heard in the urban schools, songs that have not yet been infected by the modern idiom. The contagious spirit and enthusiasm with which these songs are sung is further evidence of the vitality and continuity of tradition. A large literature of choral music composed by mission-trained African composers and notated in the British *tonic sol fa* notation, is popular with the innumerable choruses. Children learn to sight-read this music with remarkable accuracy and the performance of these works in four-part harmony as sung by the colorful African voices is most impressive. The quality of performance depends upon the musicality of the teachers, none of whom is specially trained in music.

Having accepted European culture as a desirable and necessary adjunct to his inherited native culture, the African is interested in performing and enjoying European music. He labors with this foreign material with a tenacity that is admirable, but his results are often pathetic, for he is completely lacking in background, insight, and technique for performing this music. I have heard the Elizabethan madrigal, *My Bonny Lass, She Smileth,* by Thomas Morely, sung by primary school children in a funereal tempo and with irregularities that betrayed a lack of understanding of the composition by both teacher and pupils. This desire to share in the musical culture of the world is worthy of praise and any attempt to discourage it is unrealistic and immoral. Purists fear that a knowledge of and participation in the musical culture of the West will destroy the indigenous musical culture. May I remind them that the African's ability to speak English has not destroyed his native language. It has enlarged the vocabulary through the introduction of English words, but the basic structure and character of the native language have not been violated. If the African can be bilingual as he is, he can also be bimusical, by which I mean an ability to perform the music of two cultures with due respect for the style and character of each. The Rhodesian Academy of Music in Bulawayo, under the imaginative direction of R. B. Sibson, in a valiant attempt to implement the principle of "partnership" declared by the government upon

the founding of the Federation has initiated a program of studies for African students. This program, based on a sound and realistic philosophy, is bound to succeed despite the difficulties that it is encountering in its early years.

Instrumental music is less developed than choral music and plays a much smaller role in the Federation than in other parts of Africa. Drums of varying sizes and shapes are used to accompany singing, but much singing is done without drum accompaniment. The most sophisticated instrument, one that demands of the player a highly developed technique, is the *mbira*, known also as the *sansa*, or Kaffir piano. The skill required for the building and playing of the instrument is found today only among a few old men. The younger generation has shown little interest in the building or playing of the *mbira*. The ubiquitous guitar that can be purchased for a few pounds has caught the fancy of the young men and appears to be displacing the native *mbira*. It remains to be seen what effect this instrument with its tonic, dominant, and subdominant harmonies will have on African music. The musical bow and bamboo transverse flutes are found in this area but they are not common.

Tribal and racial consciousness have found explicit and forthright statement in song, and Africans have availed themselves of its use in promoting their drive toward nationalism and independence from colonialism. The text of the following song was recorded in 1959 as sung by the children of Standard III (the equivalent of the fifth grade in United States public schools) at a government school in Bulawayo.

> "The Matabele are a very proud people.
> They came from far away in Zululand.
> They took an axe and made it theirs
> And the girls were also theirs."

A hymn, *Nkosi Sikelel' iAfrica*, composed by a mission-trained African near the end of the last century and translated into several languages has been unofficialy adopted as the African national anthem of South and Central Africa. It has been a dominant factor in raising Africans above the xenophobia of tribalism into a conciousness of their race.

The Northern Rhodesia African National Congress has as its main aim, opposition to the Federation has been most successful in promoting its cause through the use of political songs. Choirs in the various districts of Northern Rhodesia have rallied support for the Congress through songs, a medium that communicates directly with the masses. The Independence Choir of Lusaka, under the direction of Isaac Banda, has a repertoire of 50 or more songs, all the compositions of Banda. Most of the songs are in Nyanja, but several of them are in English, undoubtedly for the benefit of the Europeans. The simple beauty of the poem of the following song expresses the feeling of Banda and his fellow Africans for their native land.

"Look at the beautiful trees on the mountain.
Look at the beautiful grass in the valleys.
Look at the fish in the rivers, Oh!
How beautiful is my father's country.

Look at the copper in the mines.
Look at the cultivated plants in the gardens.
Look at the animals in the forests, Oh!
How beautiful is my father's country.

Oh! Rhodesia, my father's country,
Oh! Rhodesia, go not out of my hand
Whatever may happen.
As you are my father's country
So you are mine."

The goal of the African National Congress is succinctly stated in *We Want Freedom Now, Just Now,* composed and sung in English. Although made for the Northern Rhodesia Congress, its significance extends beyond the geographic boundaries of this territory of the federation, for it proclaims the dominant theme of all Africans today: *We Want Freedom Now, Just Now.*

"Whenever you people cast your votes
For Harry Nkumbula of Africa
You vote for freedom now.
For Nkumbula is the true Moses
This country of ours ever had,
The destroyer of Federation.
We pay our respects to all
Members of this Legico (Legislative Council),
Those members siding with Nkumbula
In the liberation of Africa.
A black man is busy everywhere
Preparing himself for freedom now.
For this is truly African time.
Whatever happens he will be free."

The music of Banda's songs reflects considerable Western influence and, for that reason, would be frowned on and discredited by those students who refuse to recognize culture change in music. It is not for the ethnomusicologist to pass value judgments on the music he studies, especially when those pronouncements are apt to be unconsciously influenced by Western standards not applicable to non-Western music. His task is to study all music in its cultural setting for what it can reveal of man and his spiritual life. Government administrators, educators, and foundations have been slow in recognizing the important role that music plays in the lives of the Africans. I do not advocate its use for propaganda purposes,

but I strongly recommend its study and appreciation as a happy medium of communication and rapprochement.

Acknowledgment

I gratefully acknowledge financial help from the United States Educational Commission in the United Kingdom (Fulbright), London, England, from the American Council of Learned Societies, and from the Ruth M. Knight Foundation, both in New York, N. Y.

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2. UPPSALA UNIVERSTETS ARSSLRIFT. 1960. Acta Universitatis Upsaliensis. Uppsala ab Lundequistaka Borhandeln. Also published as Studia Mi sionalia Upsaliensia. Translated into English by Eric J. Sharpe.

CONFERENCE HELD

SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

MULTIPLE MOLECULAR FORMS OF ENZYMES

Wednesday, February 1
Thursday, February 2, and
Friday, February 3, 1961

Conference Cochairmen

Kenneth F. Gregory, Ontario Agricultural College
Guelph, Ont., Canada
and
Felix Wroblewski, Memorial Center for Cancer and
Allied Diseases, New York, N.Y.

WEDNESDAY, FEBRUARY 1, 1961

Session Chairman: K. F. Gregory
Ontario Agricultural College, Guelph, Ont., Canada

9:00 A.M. –
Greetings from the Academy - Charles Noback, Chairman, Section of Biological and Medical Sciences, The New York Academy of Sciences, New York, N.Y.; and College of Physicians and Surgeons, Columbia University, New York, N.Y.

"Opening Remarks" - K. F. Gregory, Ontario Agricultural College, Guelph, Ont., Canada.

"Chromatographic Heterogeneity of Some Enzymes in Mammalian Tissues and Tumors" - B. W. Moore and Pietro U. Angeletti, Washington University, St. Louis, Mo.

"Molecular Variation in Similar Enzymes from Different Species" - John Paul, Glasgow University, Glasgow, Scotland.

"Physicochemical Nature of Isozymes" - C. L. Markert and Ettore Appella, Johns Hopkins University, Baltimore, Md.

"Chemical Differences between Multiple Forms of Lactic Acid Dehydrogenases" - Th. Weiland and G. Pfleiderer, Johann Wolfgang Goethe University, Frankfurt-am-Main, West Germany.

Session Chairman: E. J. King
Postgraduate Medical School, London, England

2:00 P.M. –

"The Evolution and Differentiation of Dehydrogenases" - N. O. Kaplan, M. M. Ciotti, and R. McKay, Brandeis University, Waltham, Mass.

"Multiple Peroxidases in Corn" - D. C. McCune, Boyce Thompson Institute for Plant Research, Yonkers, N.Y.

"The Chromatographic Forms of Cytochrome c" - E. Margoliash and J. A. Lustgarten, McGill-Montreal General Hospital Research Institute, Montreal, P. Q., Canada.

"Nuclear and Cytoplasmic Factors Determining the Species Specificity of Enzyme Proteins in *Acetabularia*" - K. Keck, Johns Hopkins University, Baltimore, Md.

"Genetic Control of the Esterases in the Protozoan *Tetrahymena pyriformis*" - Sally L. Allen, University of Michigan, Ann Arbor, Mich.

THURSDAY, FEBRUARY 2, 1961

Session Chairman: C. L. Markert
Johns Hopkins University, Baltimore, Md.

9:00 A.M. –

"Various Forms of *D*- and *L*-Lactic Dehydrogenases in Yeast" - A. P. Nygaard, University of Oslo, Blindern, Oslo, Norway.

"Enzymes Dehydrogenating Lactate in Yeast" - E. Boeri, M. Rippa, and T. Cremona, Istituto di Fisiologia Umana, Ferrara, Italy.

"The Formation and Enzymatic Properties of the Various Lactic Dehydrogenases of Yeast" - C. Gregolin, Edna B. Kearney, and T. P. Singer, Edsel B. Ford Institute for Medical Research, Detroit, Mich.

"Multiple Forms of Yeast Hexokinase" - Akira Kaji, School of Medicine, Vanderbilt University, Nashville, Tenn.; Kenneth A. Trayser, The McCollum-Pratt Institute, The Johns Hopkins University, Baltimore, Md.; and S. P. Colowick, School of Medicine, Vanderbilt University, Nashville, Tenn.

"Isolation and Kinetics of Two Forms of Fumarase from Torula Yeast" - Selma Hayman and R. A. Alberty, Department of Chemistry, University of Wisconsin, Madison, Wis.

Session Chairman: Felix Wroblewski
Memorial Center for Cancer and Allied Diseases, New York, N.Y.

2:00 P.M. –

"Introductory Remarks" - Felix Wroblewski, Memorial Center for Cancer and Allied Diseases, New York, N.Y.

"Localization of Serum Leucine Aminopeptidase, 5-Nucleotidase and Nonspecific Alkaline Phosphatase by Starch Gel Electrophoresis–Clinical and Biochemical Significance in Disease States" - O. D. Kowlessar, Lorraine J. Haeffner, and Earla M. Riley, New York Hospital-Cornell Medical Center, New York, N. Y.

"Multiple Forms of Esterases Present in Vertebrate Plasma" - K. B. Augustinsson, University of Stockholm, Stockholm, Sweden.

"Separation and Characterization of Lactic Dehydrogenases from Serum and Formed Elements of Human Blood" - B. R. Hill and E. J. Meacham, City of Hope Medical Center, Duarte, Calif.

"Studies on the Significance of Lactic Dehydrogenase Heterogeneity in Human Blood and Tissues" - E. S. Vesell, The Rockefeller Institute, New York, N.Y.

"On The Fifth, Electrophoretically Slowest, Serum LDH As An Index of Liver Injury" - R. J. Wieme and Y. Van Maercke, Laboratory of the Medical Clinic, University of Ghent, Ghent, Belgium.

FRIDAY, FEBRUARY 3, 1961

Session Chairman: E. G. Krebs
University of Washington, Seattle, Wash.

9:00 A.M. –

"Lactic Dehydrogenase Isoenzymes and their Distribution in Plasma in Disease States" - Felix Wroblewski, Memorial Center for Cancer and Allied Diseases, New York, N.Y., and K. F. Gregory, Ontario Agricultural College, Guelph, Ont., Canada.

"Isoenzymes in the Human Epidermis" - G. Weber and G. Pfleiderer, Hautklinik und Medizinische Poliklinik der Universität, Mainz, West Germany.

"Multiple Forms of Lactic Dehydrogenase in Tissues of the Mouse, Their Specificity and Responses to Altered Physiological Conditions"–J. M. Allen, University of Michigan, Ann Arbor, Mich.

"Heterogeneity of the Polyamine Oxidase of Plasma, Ceruloplasmin"–Shalom Hirschman, A. G. Morell and I. H. Scheinberg, Albert Einstein College of Medicine, Yeshiva University, New York, N.Y.

"Immunochemical Studies of Functionally Similar Enzymes"–J. S. Nisselbaum, Memorial Center for Cancer and Allied Diseases, New York, N. Y.; Max Schlamowitz, Roswell Park Memorial Institute, Buffalo, N. Y.; and Oscar Bodansky, Memorial Center for Cancer and Allied Diseases, New York, N. Y.

Session Chairman: N. O. Kaplan
Brandeis University, Waltham, Mass.

2:00 P.M. –

"Serological Differentiation of Amylase Isozymes" - R. L. McGeachin and J. M. Reynolds, University of Louisville School of Medicine, Louisville, Ky.

"Ribonucleases *a* and *b*" - B. C. G. Carter and B. Cinader, University of Toronto and Ontario Cancer Institute, Toronto, Ont., Canada.

Open Discussion on the Nomenclature of Multiple Forms of Enzymes and the Criteria for Distinguishing These from Distinct Enzymes.

SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

Charles Noback
Chairman

Preston L. Perlman
Vice-Chairman

THE USE OF ANIMAL CELL, TISSUE, AND ORGAN CULTURES IN RADIOBIOLOGY

Thursday, February 16
Friday, February 17, and
Saturday, February 18, 1961

Conference Cochairmen

Charles M. Pomerat
The Pasadena Foundation for Medical Research
Pasadena, Calif.
and
David C. White
Armed Forces Institute of Pathology
Bethesda, Md.

THURSDAY, FEBRUARY 16, 1961

Session Chairman: C. M. Pomerat
The Pasadena Foundation for Medical Research
Pasadena, Calif.

9:00 A.M.–

Greetings from the Academy - Charles Noback, Chairman, Section of Biological and Medical Sciences, The New York Academy of Sciences, New York, N.Y.; Columbia University, College of Physicians and Surgeons, New York, N.Y.

Opening Remarks - C.M. Pomerat, The Pasadena Foundation for Medical Research, Pasadena, Calif.

"Growth Patterns in X-Irradiated HeLa Cells" - L. J. Tolmach, Washington University School of Medicine, St. Louis, Mo.

"X-Ray Effects on Cultured Human Amnion Cells" - J. Fogh, Sloan-Ketting Institute, Walker Laboratory, Rye, N.Y.

"Radiation Responses of Cell Strains Maintained in Continous Culture":

I. "Exploration of Biological Effects of Radiation on Rat and Human Cell Strains" - George O. Gey, Margaret K. Gey, and William Fitz-William, The Johns Hopkins Hospital, Baltimore, Md.

II. "Attempts at Influencing Radiation Response of Tumor Cell Strains with Synkavit" - Annelies Schleich, Institut für Krebsforschung, University of Heidelberg, Heidelberg, West Germany; Margaret K. Gey and George O. Gey, The Johns Hopkins Hospital, Baltimore, Md.

"Response of Neoplastic Cells *in Vitro* to Ionizing Radiation" - Anna Goldfeder, Cancer and Radiobiological Research Laboratory, Department of Hospitals, New York University, New York, N.Y.

"Survival Curves for Tumor Cells Irradiated *in Vivo*" - H. B. Hewitt, Westminster School of Medicine, London, England.

Session Chairman: Austin Brues
Argonne National Laboratory
Argonne, Ill.

2:00 P.M. –

"Radiobiological Observations on Human Hemic Cells *in Vivo* and *in Vitro*" - Edwin E. Osgood, University of Oregon, Portland, Ore.

"Qualitative and Quantitative Effects of X Ray on Lymphocytes" - R. Schrek, Veterans Administration, Edward Hines, Jr. Hospital, Hines, Ill.

"Cytocidal Effects of Radiation on Organ Culture" - O. A. Trowell, Radiobiological Research Unit, Harwell, England.

"The Effect of Ionizing Radiation on Mouse Embryonic Organs Developing *in Vitro*" - Elio Borghese, Comitato Nazionale per le Ricerche Nucleari, Frascati, Italy.

"The Effect of X Rays on Cellular Differentiation in Organ Culture" - Ilse Lasnitzki, Strangeways Research Laboratory, Cambridge, England.

FRIDAY, FEBRUARY 17, 1961

Session Chairman: O. A. Trowell
Radiobiological Research Unit
Harwell, England

9:00 A.M. –

"Chromosomal Studies on Irradiated Leukocytes *in Vitro*" - Y. Ohnuki, A. Awa, and C.M. Pomerat, Pasadena Foundation for Medical Research, Pasadena, Calif.

"The Effect of X Irradiation on the Progress of Strain U-12 Fibroblasts Through the Mitotic Cycle" - Helen Harrington, Western Reserve University, Cleveland, Ohio.

"Radiation Effects on the Division Cycle of Mammalian Cells *in Vitro*" - J. E. Till, University of Toronto, Toronto, Ont., Canada.

"Irradiation of Selected Parts of Single Cells" - T. R. Munro, Strangeways Research Laboratory, Cambridge, England.

"The Grasshopper Neuroblast Culture Technic and Its Value in Radiobiological Studies" - J. G. Carlson, University of Tennessee, Knoxville, Tenn.

Session Chairman: J. G. Carlson
University of Tennessee
Knoxville, Tenn.

2:00 P.M. –

"DNA Synthesis of Mammalian Kidney Cells in Tissue Culture after Single and Periodic Doses of Irradiation" - Agnes N. Stroud and Austin M. Brues, Argonne National Laboratory, Argonne, Ill.

"Lethal Effects of Irradiation and Nucleic Acid Metabolism in Cultured Human Cells" - R. B. Painter and W. L. Hughes, Battelle Memorial Institute, Columbus, Ohio; Medical Research Center, Brookhaven National Laboratory, Upton, N.Y.

"The Effect of Intranuclear Radiation on Cell Growth in Spinner Culture" - P. C. Sanders, D. F. Peterson, and W. H. Langham, University of California, Los Alamos Scientific Laboratory, Los Alamos, N.Mex.

"Some Limitations of Labeled Compounds in Radiobiological Investigations of DNA Synthesis" - W. B. Looney, Radiobiological Laboratory, The Johns Hopkins Hospital, Baltimore, Md.

SATURDAY, FEBRUARY 18, 1961

Session Chairman: David C. White
Armed Forces Institute of Pathology
Washington, D.C.

9:00 A. M. –

"Mammalian Cell Culture Methods in Investigating Modification of the Radiation Response" - Robert Bases, Sloan-Kettering Institute for Cancer Research, New York, N.Y.

"RNA as a Protective Agent Against Irradiation of Cell Cultures" - Donald E. Rounds, Pasadena Foundation for Medical Research, Pasadena, Calif.

"Modifying Effects of FUDR and BUDR on the Relative Biological Effect of A Spontaneous Lymphatic Tumor" - J. R. Andrews, National Cancer Institute, National Institutes of Health, Bethesda, Md.

"Studies on Radioprotection of Various Compounds *in Vitro* and *in Vivo*" - Annelies Schleich, Institut für Krebsforschung, University of Heidelberg, Heidelberg, West Germany.

SECTION OF BIOLOGICAL AND MEDICAL SCIENCES

Charles Noback
Chairman

Preston L. Perlman
Vice-Chairman

NEW MEMBERS

Elected February 23, 1961

LIFE

Blake, Eugene M., M.D., Ophthalmology. Clinical Professor, Emeritus-Ophthalmology, Yale University, New Haven, Conn.

Grinnell, Alan D., Sensory Physiology, Junior Fellow, Harvard University, Society of Fellows, Harvard Biological Laboratories, Cambridge, Mass.

Hutchin, Peter, M.D., Surgery. Assistant Resident in Surgery, Grace New Haven Hospital, New Haven, Conn.

Michel, Philippe B., Ph.D., Psychiatry, Clinical Director at Provincial Hospital Campbellton, N.B., Canada.

Perrier, M. Frantz, Lic. Es Sci., Optique Electronique, Professeur à la Faculté des Sciences de Toulouse, Toulouse, France.

Purana nanda, Chaloem, M.D., Microbiology. Director, Queen Scavabha Institute, Bangkok, Thailand.

Traut, Herbert F., M.D., Gynecology. Professor of Obstetrics, University of California Medical School, San Francisco, Calif.

SUSTAINING

Conti, Joseph Powell, D.O. Endocrinology. Private Practice, Dallas, Texas.

Junqueira, Antonio C. C., M.D., Medical Sciences. Chemotherapyst (cancer) of Instituto do Cancer de São Paulo, São Paulo, Brazil.

Morris, William S., A.B., Psychometrics. General Partner, William S. Morris & Co. (investment bankers), New York, N.Y.

Quinones-Jimenez, N. Jr., M.D. Medical Sciences. Clinical Professor, Opthalmology School of Medicine, University of Puerto Rico, Santurce, Puerto Rico.

ACTIVE

Adamson, Richard H., M.S., Drug Metabolism. Fellow, Department of Pharmacology, College of Medicine, State University of Iowa, Iowa City, Iowa.

Antliff, Harold Roy., Ph.D., Endocrinology. Director and Owner, Central Bio-Clinical Laboratory, Calgary, Alberta, Canada.

Austin, Bascum O., E.E., Electrical Engineering Consultant. Westinghouse Electric Corp., Lima, Ohio.

Austin, Kenneth L., Diploma-Sorbonne, Biological and Medical Sciences. Research Assistant, Tobacco Industry Research Committee, New York, N.Y.

Avren, Stanley S., M.D., Allergy. Private Practice, Victoria, B.C., Canada.

Axelrod, Julius, Ph.D., Biochemistry, Chief, Section Pharmacology, National Institute of Health, Bethesda, Md.

Azar, Joseph E., M.D., Tropical Diseases. Associate Professor of Tropical Health, American University of Beirut, Beirut, Lebanon.

Babcock, Kenneth L., Ph.D., Soil Chemistry. Assistant Professor, University of California, Berkeley, Calif.

Babey, Andrew, M.D., Internal Medicine. Cardiologist, Private Practice, Las Cruces, N. Mex.

Backus, George E., Ph.D., Geophysics and Hydromagnetics. Associate Professor of Mathematics, University of California, La Jolla, Calif.

Backus, John King, Ph.D., Physical Chemistry of Polymers. Research Supervisor, General Mills, Inc., Tonawanda, N.Y.

Banker, Harry W., M.D. Medicine, Radiologist, Terrell's Laboratories, Fort Worth, Texas.

Banks, Ephraim, Ph.D., Inorganic Chemistry. Professor of Inorganic Chemistry, Polytechnic Institute of Brooklyn, Brooklyn, N.Y.

Bedell, Ralph, Ph.D., Psychology and Education, Chief, Counseling and Guidance Institutes Section, U.S. Office of Education, Washington D.C.

Benichoux, Roger Joseph, Prof. Agrégé, Surgery and Cardiac Surgery. In charge, Laboratoire de Chirurgie Expérimentale Faculté de Médecine, Nancy, France.

Bernstein, Sol, M.D., Medicine. Instructor in Medicine, University of Southern California, Los Angeles, Calif.

Bibbero, Robert J., M.S.E.E., Control System Engineering. Chief Electronics Engineer, Bulova Research and Development Labs., Inc., Woodside, N.Y.

Biel, Erwin Reinhold, Ph.D, Climatology. Professor and Research Specialist, Department of Meteorology, Rutgers University, New Brunswick, N.J.

Bijaard, Paul Peter, Civil Eng., Stability. Professor of Mechanics, Cornell University, Ithaca, N.Y.

Bingham, Marjorie T., M.A., Biology. Head, Department of Biology, Centenary College for Women, Hackettstown, N.J.

Birch, Norman Anton, S.B., Metallurgy. Technical Director, Albion Malleable Iron Co., Albion, Mich.

Bismanis, Jekabs Edwards, M.D., Bacteriology. Assistant Professor, University of British Colombia, Vancouver, B.C., Canada.

Blank, Charles A., Ph.D., Physical-Inorganic Chemistry. Physicist, Department of Defense, Washington, D.C.

Blankner, Fredericka, Litt.D. Psychology of the Arts. Adelphi College, Garden City, N.Y.

Blomquist, Alferd T., Ph.D, Chemistry. Professor of Chemistry, Cornell University, Ithaca, N.Y.

Bogusz, Józef, M.D., Surgery, Director of the I Department of Surgery, Academy of Medicine, Kraków, Poland.

Bohus, Emil M., B.A., Pharmacology and Biology. Junior Pharmacologist, Smith, Kline and French Labs., Philadelphia, Pa.

Bowman, Jeanne T., M.D., Cancer. Resident in Radiology, Chicago Wesley Memorial Hospital, Chicago, Ill.

Boy, Jaques, M.D., Biological and Medical Sciences. Biologist, Hospital De Reims, Reims, France.

Brigham, Virginia M., Ph.D., Electronics and Spectroscopy. Chairman, Physics Department, Simmons College, Boston, Mass.

Brooks, John Robinson, M.D., Endocrine Tissue Transplantation. Clinical Associate in Surgery, Harvard Medical School, Boston, Mass.

Campbell, Robert J., M.D., Biological and Medical Sciences. Director, Psychiatric Residency Training Program, St. Vicent's Hospital, New York, N.Y.

Carles, Jules, D.Sc., Physiologie vegetale et Biochimie. Professor, Institute Catholique, Toulouse, France.

Cass, Abraham, Microbiology. University of Miami, Coral Gables, Fla.

Celmer, Walter D., Ph.D. Bio-organic Chemistry. Research Supervisor, Medical Research Laboratories, Chas, Pfizer & Co., Inc., Groton, Conn.

Chaney, George C., M.D., Pathology. Pathologist, Van Atta Laboritories, Presbyterian Hospital Center, Albuquerque, N. Mex.

Chaudhury, Ranjit Roy, D.Phil., Physiology. Post Doctoral Fellowship of National Research Council of Canada, Ottawa, Ont. Canada.

Christiano, Rita J., B.A., Research Chemist. Bristol-Myers Co., Hillside, N.J.

Collins, Margaret S., Ph.D., Insect Physiology. Research Fellow, University of Minnesota, St. Paul, Minn.

Colwin, Laura Hunter, Ph.D., Developmental Biology. Lecturer in Biology, Queens College, Flushing, N.Y.

Cooke, Robert S. Jr., M.D., Medical Sciences. Associate Pathologist, Pathology Laboratory, Hattiesburg, Miss.

Crane, Robert Kellogg, Ph.D., Biological Chemistry, Associate Professor, Washington University Medical School, St. Louis. Mo.

Dacquisto, Michael Paul, M.D., Radiobiology. Director, Division of Nuclear Medicine, Walter Reed Medical Center, Washington, D.C.

D'Adamo, Amedeo F. Jr., Ph.D., Biochemistry. Assistant Professor, Biochemistry, Seton Hall College of Medicine and Dentistry, Jersey City, N.J.

Das, Bhupendra Chandra, Ph.D., Biometry and Physiology. Research Associate, Wayne State University College of Medicine, Detroit, Mich.

Dasher, George Franklin, Jr., Ph.D., Colloid Chemistry. Assistant Director, Research Clairol Inc., Stamford, Conn.

Dautreppe, Daniel. D.Sc., Physique du Solide. Chef du Laboratorie de Physique du Solide Centre, Grenoble (Isére) France.

De Chenar, Coloman, M.D., Histopathology. Chief, Department of Pathology, Austin State Hospital, Austin, Texas,

De Crinis, Kurt, M.D., Circulation. Associate, Drummond Medical Center, Ridgecrest, Calif.

Dennis, Edward Wimberly, M.D., Cardiology. Associate Professor, Internal Medicine, Baylor University College of Medicine, Houston, Texas.

DeStevens, George, Ph.D., Medicinal Chemistry. Group Leader in Synthetic Medicinals CIBA Pharmaceutical Products Inc., Summit, N.J.

De Tar, Reed L. Jr., M.S., Physiology. Associate Scientist, Warner-Lambert Research Institute, Morris Plains, N.J.

DeWael, Paul L., M.D., Medicine. Senior, Surgical Staff, General & Samaritan Hospitals, Bay City, Mich.

Donor, Albert E. Jr., M.S., Biology-Parasitology. Professor, Biology, Nassau College, Queens, N.Y.

Ellis, Ruth H., Ph.D., Biochemistry. Professor, Chemistry, Vassar College, Poughkeepsie, N.Y.

Epstein, Arnold I., Ph.D., Food Chemistry, Director of Research and Quality Control, The Sucher Packing Co., Dayton, Ohio.

Faefel, Bernard, M.D., Internal Medicine. Assistant Professor Clinical Medicine, Baylor University College of Medicine, Houston, Texas.

Florent, René, Dr. of Pharmacie, Biochemistry. Professor of Biology, Paris, France.

Franek, Bruno, M.D., Psychosomatic Research in Hypnosis. Consultant Psychiatrist, Rhode Island State Program for Mental Retardation, East Greenwich, R.I.

Franklin, Alan D., Ph.D., Solid State Physics. Chief, Mineral Products Division, National Bureau of Standards, Washington, D.C.

Frye, Royal Merrill, Ph.D., Nuclear Physics. Dean of Faculty, College of Advanced Science, Canaan, N. H.

Gabliks, Janis Z., M.S., Bacterial Toxins vs. Tissue Culture. Instructor, Tissue Culture, Rutgers University, New Brunswick, N.J.

Garnham, P.C.C., D.P.H., Parasitology. Head of Department of Parasitology, London School of Hygiene and Tropical Medicine, London, England.

Gibson, Robert, M.D., Mental Deficiency. Clinical Director, Manitoba School, Manitoba, Canada.

Goldfarb, Charles, M.D., Clinical Psychiatry. Research Scientist in Department of Medical Genetics, Columbia Presbyterian Medical Center, New York, N.Y.

Goldheim, Samuel L., Ph.D., Chemistry. Vice-President and Director, American Bio-Chemical Laboratory, Inc., Baltimore, Md.

Goldin, Gurston, M.D., Psychiatry. Resident Psychiatrist, Presbyterian Hospital, New York, N.Y.

Goldschmit, Leontine, Ph.D., Clinical Biochemistry. Senior Research Chemist, Creedmoor Institute, Queens Village, N.Y.

Goodman, Jerome M., M.A., Psychology. School Psychologist, Roslyn Elementary Schools, Roslyn, N.Y.

Gordon, Reuben H., D.CH., Biophysical Research. Chief of Research, Gordon-Brown Medical Instruments Co., Daytona Beach, Fla.

Goulding, Robert L., M.D., Physician. Resident in Psychiatry, Veterans Administration Hospital, Perry Point, Md.

Grant Francis C. Jr., B.A., Pharmaceutical Research. Director of Research and Development Agreements, Smith, Kline & French Laboratories, Philadelphia, Pa.

Griffin, Jack B., M.D., Medicine. Attending Staff, Baylor Hospital, Dallas, Texas.

Griffith, Rosemary M., M.S., Meteorology. Member of Technical Staff, RCA Surface Communications Laboratory, New York, N.Y.

Grosberg, Saul J., M.D., Gastroenterology. Senior Resident, Veterans Administration Hospital, Brooklyn, N.Y.

Gulick, W. Lawrence, Ph.D., Physiological Psychology. Assistant Professor of Psychology, University of Delaware, Newark, N.J.

Hanowell, Ernest, G., M.D., Cardiopulmonary Research. Assistant Professor of Medicine, Hahnemann Medical College, Philadelphia, Pa.

Hard, Richard C. Jr., M.D., Tissue Transplantation. Resident Fellow in Pathology, St. Louis University School of Medicine, St Louis, Mo.

Hasegawa, Junji, M.D., Medicine. Instructor in Dermatology, Northwestern University Medical School, Chicago, Ill.

Hill, Robert, Ph.D., Intermediary Metabolism. Scientific Director, Diablo Laboratories Inc., Berkely, Calif.

Hirschhorn, Sigmund A., M.D., Cardiology. Private Practice, Brooklyn, N.Y.

Hirt, Susanne, B.S., Anatomy. Technical Director, School of Physical Therapy, Medical College of Virginia. Richmond, Va.

Hitchcock, Dian R., B.A., Artificial Intelligence. Member of Technical Staff, Thompson Ramo Wooldridge, Canoga Park, Calif.

Hoffman, Seymour, D.D.S., Oral Pathology. Graduate Student and Resident in Training, Boston University School of Medicine, Boston, Mass.

Infante D. Salvador, M.D., Biological and Medical Sciences. Head of the Department of Surgery, Universidad de El Salvador, San Salvador, El Salvador.

Isakower, Otto, M.D., Psychology. Faculity Member, New York Psychoanalytic Institute, New York, N.Y.

Isokane, Robert K., M.S., Tropical and Comminicable Diseases. Microbiologist, U.S. Naval Hospitals, San Diego, Calif.

Ives, Ronald L., Ph.D., Geophysics. Electronic Engineer, Stanford Aerosol Laboratory, Stanford, Calif.

Jackson, George R., Ph.D., Organic Chemistry, President of Top-Scor Products, Inc., Louisville, Ky.

Janov, Arthur, Ph.D., Child Psychotherapy, Psychologist, Private Practice, Palm Springs, Calif.

Jencks, Beata, M.A., Psychology. Graduate Student, University of Utah, Salt Lake City, Utah.

Johnson, James W., M.S., Virology. Bacteriologist Fort Detrick, Frederick, Md.

Joiner, Hartwell, M.D., Common Colds and Cancer. Private Practice, Gainesville, Ga.

Jones, J. Paul, Jr., M.D., Medicine. Chief Resident, Lenox Hill Hospital, New York, N.Y.

Jungblut, Edith Josette, B.A., Epidemiology of Degenerative Diseases. Analytical Statistician, U.S. Public Health Service, Washington, D. C.

Kaesz, Herbert David, Ph.D., Inorganic Chemistry, Assistant Professor, Department of Chemistry, University of California, Los Angeles, Calif.

Kelly, John Joseph, Jr., M.D., Cardiovascular Pulmonary. Director, Cardiovascular Pulmonary Center & Medical Education, Mercy Hospital, San Diego, Calif.

Kent, Stephen Gabriel, M.D., Autonomic Nervous System. Pathology, The New York Hospital, Cornell Medical Center, New York N.Y.

Ketusinh, Ouay, M.D., Physiology. Professor and Director, Department of Physiology, Siriraj Hospital, Bangkok, Thailand.

Kiefer, Lester, M.D., Radiopathology. Assistant Professor, Department of Pathology, University of Maryland School of Medicine, Baltimore, Md.

Kincaid, Clement J., D.D.S., Biology, Private Practice, Chicago, Ill.

Kitchen, B.F., M.D., Orthopedic Surgery. Partner-Chelsea Orthopedic Clinic, Houston, Texas.

Kliwer, John H., M.D., Psychiatry. Member of Faculty, University of Virginia, Charlottesville, Va.

Kogan, B.A., Ph.D., Medicine. Torrance District Health Officer, Los Angeles County Health Department, Torrance, Calif.

Krol, Stefan, Proteolytic Enzymes. Ethicon Inc., Somerville, N.J.

Law, William Alexander, M.D., Orthopaedic Surgery. Consultant Orthopaedic Surgeon, The London Hospital, London, England.

Leavitt, Frederick C., Ph.D., Organic Chemistry of Polymers. Research Chemist, Dow Chemical Co., Research Laboratory, Framingham, Mass.

Lebrun, Jacques, M.D., Cancer-Surgery. Attending in Surgery, Institut Bordet, Centre des Tumeurs de l'Universite de Bruxelles, Belgium.

Lee, John M., M.D., Medicine, Pathologist, Private Practice, Elmwood Park, Ill.

Lewis, Archdale Sydney, M.D., Medicine. Chief, Medical Advisory Staff, St. Johns, Newfoundland, Canada.

Lewis, Urban J., Ph.D., Biochemistry, Research Biochemist, Merck Sharp & Dohme Laboratories, Rahway, N.J.

Lincoln, Edith M., M.D., Chest Diseases. Adjunct Professor of Pediatrics, New York, College of Medicine, New York, N. Y.

Lindberg, Morgan C., M.D., Dermatology. Private Practice, North Hollywood, Calif.

Mable, Kenneth W., D.Sc., Biological and Medical Sciences, Physiotherapist, Private Practice, Endicott, Union Station, N.Y.

Mann, William A., B.S., Pharmacology. Pharmacologist, Smith, Kline and French Labs. Philadelphia, Pa.

Manner, Richard J., M.D., Medicine. Associate Director of Clinical Research, Mead Johnson Research Center, Evansville, Ind.

Mariani, Luigi, M.D., Pharmacology. University of Milan, Milan, Italy.

Martinek, Johann, Dr. Ing., Math, Biophysics. Staff Scientist, Reed Research Foundation, Washington, D.C.

Mason, Clyde Walter, Ph.D., Chemical Microscopy. Professor of Metallography, Cornell University, Ithaca, N.Y.

Mavridis, Paraskeri, Ph.D., Insect Nerve Physiology. Research Associate, Department of Biological Science, Purdue University, Lafayette, Ind.

Maynard, Russell M., M.D., Pathology. Chief of Laboratory Service, Veterans Administration Center, Wood, Wis.

Migone, Luigi, M.D., Internal Medicine. Director, Institute of Medical Pathology, University of Parma, Parma, Italy.

Milton, Robert M., Ph.D., Cryogenics. Assistant Director of Research, Linde Co., Tonawanda, N.Y.

Miraglia, Gennaro John, Ph.D., Host-parasite relationships. Post-doctoral fellow (NIH), Department of Biology, Bryn Mawr College, Bryn Mawr, Pa.

Miytake, Isami Sam, M.D., Internal Medicine. Intern, Jersy City Medical Center, Jersey City, N.J.

Molander, David W., M.D., Medicine. Instructor, Cornell College of Medicine, New York, N.Y.

Montalenti, Giuseppe, Ph.D., Genetics. Director, Istituto di Genetica, Faculty of Science, University of Rome, Rome, Italy.

Moore, Walter D. Jr., M.D., Pathology, Pathologist, Madonna Hospital, Denison, Texas.

Mukerji, B., D.Sc., Biological and Medical Sciences. Director, Central Drug Research Institute, Lucknow, India.

Mullin, Albert Alkins, S.M.E.E., Mathematical logic and electrical Engineering. Research Mathematican, University of Illinois, Urbana, Ill.

Murray, David Stark, M.B., Leukemia and Cancer in general. Director, Group Laboratory, Kingston on Thames, Surrey, England.

Natarajan, Coimbatore P., M.Sc., Food Reaserch, Senior Scientific Officer, Central Food Technological Research Institute, Mysore, India.

Neher, Robert, Dr. Ing. Chem., Organic Chemistry. Research Chemist, CIBA Ltd., Basle, Switzerland.

Nesbitt, Robert E. L. Jr., M.D., Human Reproductive and Generative Tract Physiology, Albany Medical College, Albany, N.Y.

Nicol, Thomas, D.Sc., Reticuloendothelial System. Dean of Faculty of Medicine, University of London, King's College, Strand, London, England.

Nouvel, Jacques, Physiologie. Professeur au Muséum National d'Historie Naturelle, Director Parc Zoologique de Paris, Paris, France.

Novack, Paul, M.D., Medicine. Associate in Medicine, Director, Cardiac Physiology Laboratory, Hahnemann Medical College and Hospital, Philadelphia, Pa.

Obregon, G., M.D., Plastic Surgery. Private Practice, Sacramento, Calif.

O'Brien, George Gerald, Ph.D., Operations Research and Mathematics. Director of Operations Research, Touche, Ross, Baily and Smart, Stamford, Conn.

O'Brien, Richard Desmond, Ph.D., Biochemistry. Associate Professor, Department of Entomology, Cornell University, Ithaca, N.Y.

Olander, George A., M.D., General Surgery. Chief of Surgery, Highland Park Hospital, Highland Park, Ill.

O'Neil, James Julian, M.D., Otolaryngology. Director Respiratory Research Foundation of Nebraska, Omaha, Neb.

Oppenheim, Victor, Geology. Independent Consultant, Dallas, Texas.

Orten, James M., Ph.D., Physiological Chemistry. Professor of Physiological Chemistry, Wayne State University College of Medicine, Detroit, Mich.

Pachter, Irwin J., Ph.D., Medical Chemistry. Associate Research Chemist, Smith, Kline & French Labs, Philadelphia, Pa.

Palladino, Alphonse, A.B., Biology. Fellowship in Research, University of Rome, Rome, Italy.

Payne, Anthony Monck-Mason, M.D., Epidemiology. Department of Public Health, Yale University, New Haven, Conn.

Pieragnoli, Enrico, M.D., Medical Sciences. Associate Professor, University of Bologna, Bologna, Italy.

Porter, Charles E., M.D., Internal Medicine. Cheif of Medicine, Lloyd Noland Hospital, Fairfield, Ala.

Powell, Cedric John, B.Sc., Electron Physics. Research Physicist, Imperial College, London, England.

Prigogine, Ilya, Physical Chemistry. Professor, University of Brussels, Brussels, Belgium.

Pullman, Bernard, D.Sc., Quantum Biochemistry and Chemistry. Professor of Theoretical Chemistry, University of Paris, Paris, France.

Raitt, Jacob R., Ph.D., Pharmacology. Senior Research Pharmacologist, Smith, Kline and French Labs. Philadelphia, Pa.

Rassaert, Charles L., M.S., Cardiovascular. Associate Scientist, Warner-Lambert Research Institute, Morris Plains, N.J.

Raupp, William George, M.S., Microbiology. Research Assistant, Merck Sharp & Dohme, West Point, Pa.

Reed, Roger W., M.D., Medical Bacteriology. Professor and Chairman, Department of Bacteriology, McGill University, Montreal, Canada.

Reisfeld, Ralph A., Ph.D., Protein and Peptide Chemistry. Chemist, Mersk & Co., Rahway, N.J.

Reiskin, Allan Burt, Radiation Biology and Cancer. United States Public Health Service, Fellow in Radiation Biology and Cancer, University of Pennsylvania, Philadelphia, Pa.

Risley, Chester H., M.D., Biochemistry and Radiation Studies. Retired, Cameron, Mo.

Rosen, B., Dr. Phil., Molecular Spectroscopy. Assistant Professor, University of Liege, Liege, Belgium.

Rosen, Irving Bernard, M.D., Biological Science. Surgical Staff, New Mt. Sinai Hospital, Toronto, Ontario, Canada.

Rosenthal, Murray, B.S., Biological and Medical Science. Associate in Clinical Research, E.R. Squibb & Sons, New York, N.Y.

Ross, Donald Murray, Ph.D., Comparative Neuromuscular Physiology. Professor and Head, Department of Zoology, University of Alberta, Edmonton, Alberta, Canada.

Rowe, Howard M., A.B., Pharmacology. Assistant Scientist, Warner-Lambert Research Institute, Morris Plains, N.J.

Rutter, William J., Ph.D., Biochemistry. Associate Professor, Biochemistry, University of Illinois, Urbana, Ill.

Sakuma, Toshio, B.E., Electrical Engineering. Managing Director, Komatsu Electronics Inc., Toyko, Japan.

Sanchez, Luis Arrieta, M.D., Radiology. Chief, Department of X-Ray Hospital, Saint Tomas, Panama, Republic of Panama.

Santano, Rafael E. Ferrer, M.D., Medicine. Private Practice, Catano, Puerto Rico.

Satoskar, Rajninath S., Ph.D., Medical Sciences including Biochemistry. Assistant Professor Pharmacology, Seth G. S. Medical College, Parel, Bombay, India.

Satterthwaite, Richard W., M.D., Medicine. Research full time (own Unit), San Antonio, Texas.

Schiff, Maurice, M.D., Otolaryngology. Chief, EENT Service, U.S. Naval Hospital, Oakland, Calif.

Schneider, Helene, M.D., Tissue Culture. Research Associate, Wayne State University College of Medicine, Detroit, Mich.

Seidman, Irving, M.D., Pathology. Assistant Pathologist, Roosevelt Hospital, New York, N.Y.

Senter, Alvin D., D.D.S., Dentistry and Tissue Metabolism. Assistant Professor of Oral Biology, University of California Medical Center, San Francisco, Calif.

Sharma, K.N., M.D., Gastroenterological Neurophysiology. Post Doctoral Fellow, University of Rochester Medical School, Rochester, N.Y.

Sheth, Uttamchand K., M.D., Psychopharmacology. Professor and Head, Department of Pharmacology, Seth G.S. Medical College, Bombay, India.

Shorr, Joseph E., Ph.D., Clinical Psychology. Private Practice, Los Angeles, Calif.

Shupack, Ben, M.A., Earth Sciences. Teacher, Malverne, N.Y.

Sillo, George, M.D., Biology. Head, Service for the Treatment of Male and Female Infertility Disturbances, Frankfurt, Germany.

Skeeter, Barbara D., B.S., Engineering. Director of Public Relations, Society of Motion Picture and Television Engineers, New York, N.Y.

Slater, Edward C., M.Sc., Biochemistry. Professor and Director of the Laboratory of Physiology, Chemistry, University of Amsterdam, Amsterdam. Netherlands.

Small, William Andrew, Ph.D., Mathematics. Professor, Tennessee Polytechnic Institute, Cookeville, Tenn.

Smithers, David Waldron, M.D., Clinical Cancer Research and Radiotherapy. Director Royal Marsden Hospital, London, England.

Soffen, Gerald A., Ph.D., Biochemistry. Research Associate, Department of Biochemistry, New York University, New York, N.Y.

Sonea, Sorin, M.D., Medical Microbiology and Immunology. Professor of Bacteriology, Faculty of Medicine, Université de Montréal, Montréal, P.Q., Canada.

Sorof, Sam, Ph.D., Cancer. Senior Member, Department Head, Institute for Cancer Research, Fox Chase, Philadelphia, Pa.

Spyropoulos, Constantine S., Ph.D., Electrophysiology. Neurophysiologist, National Institutes of Health, Bethesda, Md.

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